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Port Quendall Groundwater Modeling and Analysis of Alternatives

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RETEC Project No.: 3-2438-612

Prepared for:

Port Quendall Company
110 - 110th Avenue N.E., Suite #550
Bellevue, Washington 98004

January 9, 1998

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RE005 (1 of 2)

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1 Introduction

The Port Quendall development project is a proposed development of several former industrial properties located on the shore of Lake Washington at the mouth of the May Creek drainage. The locations of the properties are shown in Figure 1-1 and include the Baxter North and South Parcels, Quendall Terminals, Barbee Mills, and Pan Abode.

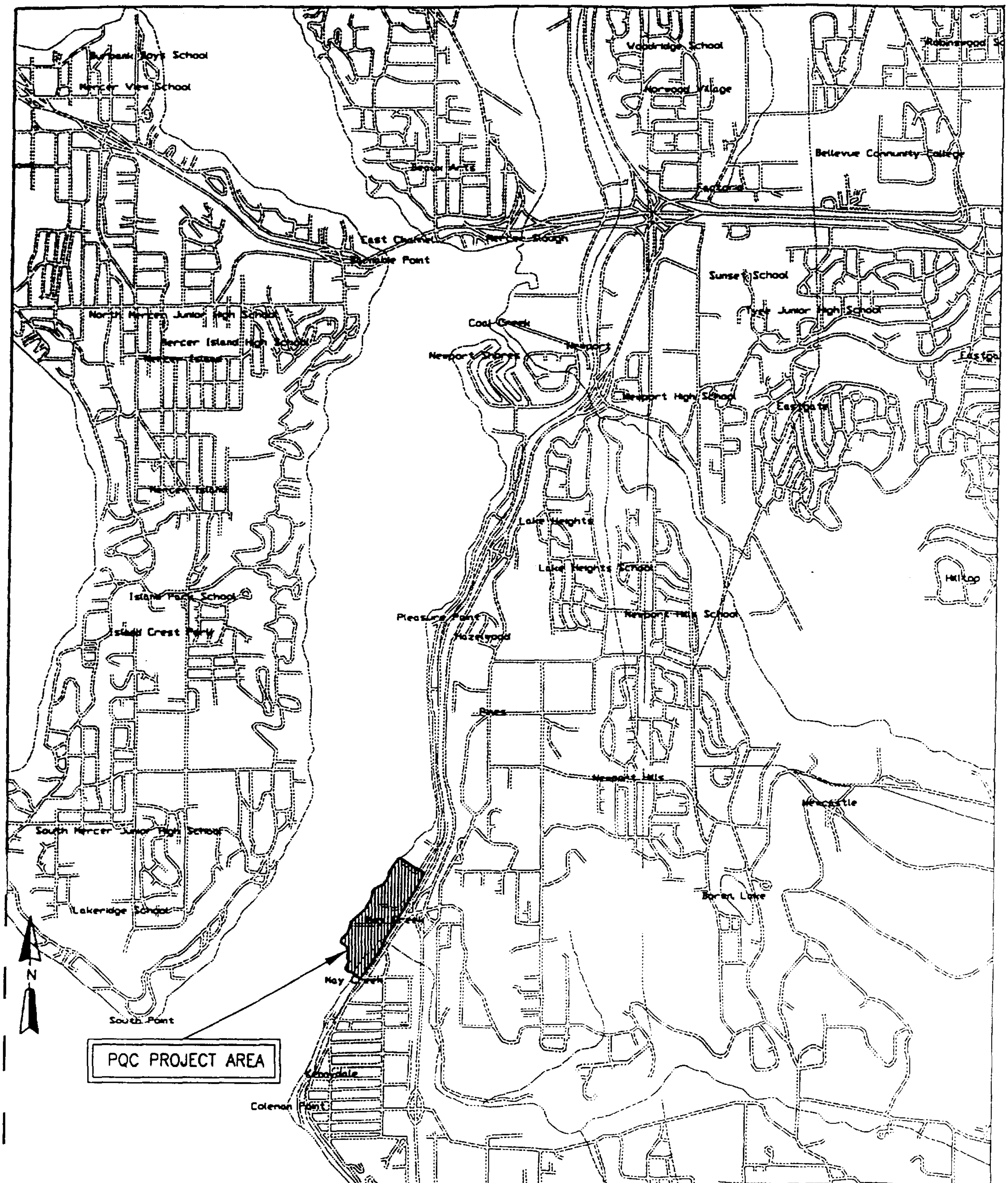
This report presents the modeling effort performed to support the Port Quendall Feasibility Study (FS)(RETEC, 1997c). This effort consisted of development of two primary models for the site: 1) a three-dimensional numerical groundwater flow model with particle tracking; and 2) an analytical fate and transport model. These models were developed to evaluate the effectiveness of various remedial alternatives considered for the project. These remedial alternatives include various configurations of containment walls, an aeration system, source removal and groundwater extraction associated with contaminated groundwater containment.

The three-dimensional hydraulic model was developed to evaluate groundwater flow conditions (the effect of various simulated remedial alternatives). Estimates of groundwater flow rates and particle tracking results obtained from the three-dimensional model were used as input to the fate and transport model. The fate and transport model was used to provide estimates of assumed point of compliance (APOC) and assumed point of exposure (APOE) chemical concentrations as a function of the remedial alternatives evaluated.

1.1 Modeling Objectives

The groundwater modeling serves to evaluate the remedial alternatives. The level of detail in the model and the modeling effort are limited to the level of analysis sufficient to achieve this purpose.

The groundwater model was developed according to existing site conditions. Once the model was calibrated to average and existing water levels, it was used to predict the remedial benefit of the various alternatives presented in Table 1-1. The remedial alternatives were evaluated in terms of groundwater travel time from the defined source areas to the APOE (point of groundwater discharge to Lake Washington), pumping rates required for groundwater capture and resulting flow patterns. The model was also used to predict dewatering rates required for source removal.



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PORT QUENDALL PROJECT AREA LOCATION

RETEC REMEDIATION TECHNOLOGIES INC

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Table 1-1 Remedial Alternatives Modeled

Three Flow Barrier Locations ▸ Upland wall (along existing shoreline) ▸ Nearshore fill area (0.5 acre) ▸ Nearshore confined disposal facility (CDF) fill area (2.9 acre)
Two Wall Depths ▸ 30 ft ▸ 50 ft
Aeration (biosparging)
Natural Attenuation
Source Removal
Groundwater Extraction ▸ Hydraulic Containment ▸ Dewatering for Excavation

1.2 Port Quendall Modeling Background

Site data are of a sufficient quantity and quality to justify a three-dimensional modeling approach. The conceptual site model is based on extensive site investigations by Remediation Technologies, Inc. (RETEC), Hart Crowser (1996), and Woodward-Clyde Consultants (1990). The site hydrogeological interpretation has been extrapolated from site boundaries to model boundaries using additional sources of information including Department of Transportation (DOT) borings, local well logs, and published regional geological interpretations. The extrapolation of the model domain beyond the site domain is necessary to minimize the boundary effects on the various alternatives being modeled. Water level data have been compiled and analyzed to characterize the seasonal variations and provide coverage for the entire model area.

Hart Crowser (1996) completed a draft remedial investigation for the Quendall Terminals property that includes a two-dimensional flowpath model. The objective of this work was to simulate the groundwater system, estimate the depth of vertical flow components, and estimate the distance from the shore that the lake environment might be affected by contaminated groundwater discharge.

Woodward-Clyde Consultants' remedial investigation of the Baxter property (1990) did not include a groundwater modeling effort. However, some hydraulic testing was conducted.

RETEC developed a three-dimensional numerical groundwater flow model and an analytical fate and transport model for the Port Quendall Company. These models can be used to predict the effect of the remedial alternatives on groundwater flow patterns and contaminant transport. Specific issues investigated include: the feasibility of installing an aeration treatment system, the depth and horizontal alignment of a proposed containment wall, the effectiveness of source removal, the pumping rates associated with a backup pump-and-treat system, and chemical fate and transport under pre- and post-remediation conditions.

The modeling effort presented herein is based on the scope of work documented in several memoranda and correspondences. A preliminary modeling memo was submitted to Ecology in April 1997. The memorandum, Ecology comments (Ecology, 1997) and the subsequent response to Ecology comments (RETEC, 1997b) are provided in Appendix A9 and comprise the scope of work.

1.3 Disclaimer

As described in the FS state-led regulatory actions are in progress at the Baxter and Quendall sites. The Port Quendall Company due diligence work and FS are separate from those state-led actions.

Any work or work product addressed in this document or cross-referenced herein and performed or to be performed by Port Quendall Company in the identified Port Quendall project area has or will be undertaken only for purposes of determining the feasibility of the Port Quendall redevelopment project. The groundwater model was used to evaluate cleanup technologies under consideration for the Port Quendall redevelopment project. The modeling assumptions are based on the technologies as evaluated in the FS. The modeling assumptions used in this document are conservative and consistent with the objectives of the Port Quendall Company and the approach presented in the FS. This analysis may not be applicable for other approaches to site cleanup or to developments with different land use plans.

Port Quendall Company and RETEC are submitting this document with the understanding that no independent liabilities shall be assumed by Port Quendall Company under MTCA or any comparable federal or state environmental laws should Port Quendall Company elect not to complete purchase of the four subject properties.

2 Hydrogeologic Conceptual Model

2.1 Geologic and Hydrogeologic Setting

The Port Quendall development site is located on the east shore of Lake Washington. An unnamed bluff rises to the east of the site and the Kennydale Bluff rises to the south. May Creek flows across the site, discharging to Lake Washington. Through time, May Creek's alignment has changed and its flow has decreased significantly. Three layers of geologic significance are found below the site; a layer of recent fill, a layer of sediments from both Lake Washington and May Creek, and a layer of older alluvial deposits associated with the May Creek watershed. Figures 2-1 and 2-2 illustrate the geological make-up of the site.

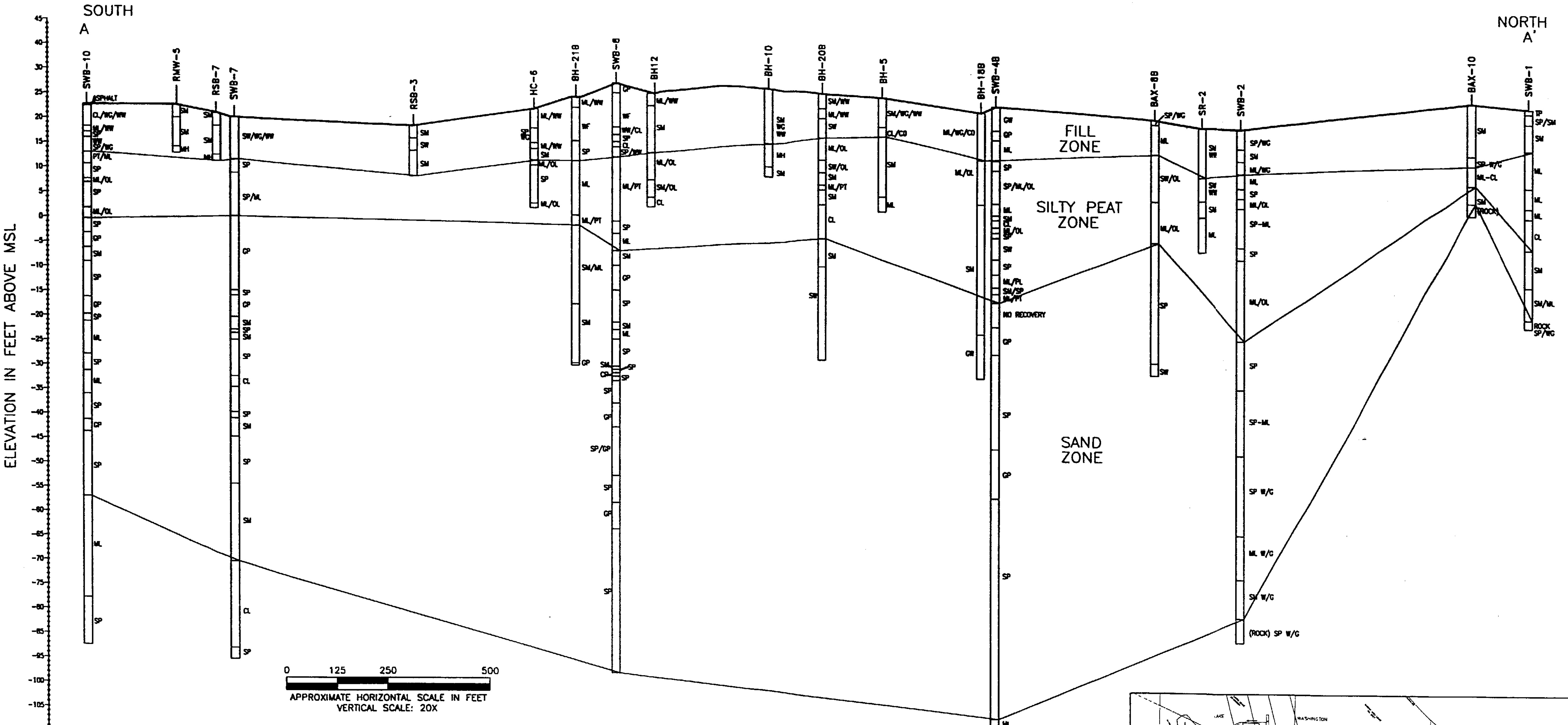
The layer of fill that covers the entire site is comprised of wood, silt, sand and gravel, extends approximately 5 ft below ground surface (bgs), and is associated with the industrial use of the property. The recent sediments associated with Lake Washington and May Creek are located 5-30 ft bgs. The layer is both vertically and horizontally heterogeneous due to sediment deposition from the lake and the changing alignments of May Creek. The layer is comprised of silty sands considered to be largely saturated. This layer is described as the silty peat zone. Environmental investigations indicate that most of the contaminant source areas are located within the silty peat zone.

The layer of old alluvial deposits associated with the May Creek drainage extend from the toe of the two bluffs north and west into Lake Washington. The sandy alluvial deposits extend from 30 to 110 ft bgs. This layer is described as the sand zone. Two recent geotechnical borings found a flowing artesian condition existing at a depth of 120 ft bgs. This is likely indicative of a deeper regional flow pattern that does not impact the local flow condition. By definition, the site hydrogeology is isolated from this artesian condition. This isolation is further supported when considering that no other wells indicate an upward gradient. Figures 2-3 and 2-4 present the top and bottom of sand elevations in feet above mean sea level.

2.2 Hydraulic Parameters

2.2.1 Hydraulic Conductivity

Hydrogeologic investigations of the silty peat zone have resulted in hydraulic conductivity estimates ranging from 0.4 to 31.2 feet per day (ft/day). The average conductivity estimate for the silty peat zone is 8.2 ft/day. The heterogeneity



NOTES

FILL ZONE

INCLUDES (1) DREDGED FILL CONSISTING OF LOOSE-TO-MEDIUM DENSE WET SILTY FINE SAND, OR FINE TO MEDIUM SAND, AND (2) DUMPED FILL CONTAINING CLAY, SILT, SAND, GRAVEL, RUBBLE, WOOD AND OTHER DEBRIS. THE DREDGED FILL MAY BE PRESENT ALONG THE FORMER LAKE WASHINGTON SHORELINES AND APPEAR SIMILAR TO THE MAY CREEK DELTAIC DEPOSITS.

SILTY PEAT ZONE

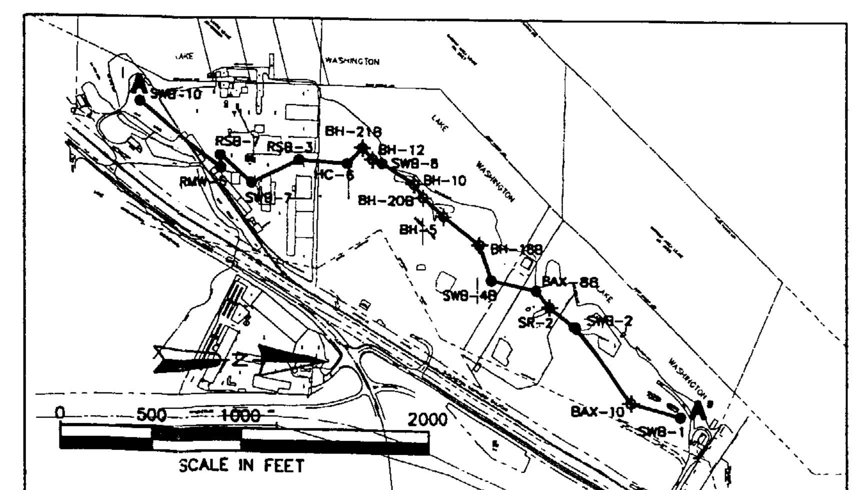
CONSISTS OF SOFT TO STIFF, DARK BROWN TO GRAY SILTY PEAT, ORGANIC WOODY SILT, AND SILTY FINE SAND WITH INTER BEDDED GRAY TO BROWN CLAY, SILT, SAND, AND OCCASIONAL ASH LENSES.

SAND ZONE

CONSISTS OF GRAY DENSE, TO MEDIUM DENSE, FINE TO COARSE GRAINED SAND, AND GRAVEL WITH COBBLES, AND INTER BEDDED GRAY SILTY FINE GRAINED SAND, AND SILT LENSES.

LEGEND

ML=SILT/SANDY SILT	WG= WITH GRAVEL
MH=CLAYEY SILT	GW=WELL GRADED GRAVEL
OL=ORGANIC SILT	GP=POORLY GRADED GRAVEL
CL=LEAN CLAY	SW=WELL GRADED SAND
CH=FLAT CLAY	SP-SM=POORLY GRADED
WF=WHITE FLY ASH	SM=SILTY SAND
WW=WOOD WASTE	SC=CLAYEY SAND
PT=PEAT	CD=CONSTRUCTION DEBRIS



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PORT QUENDALL
NORTH-SOUTH SITE
CROSS SECTION

RETEC
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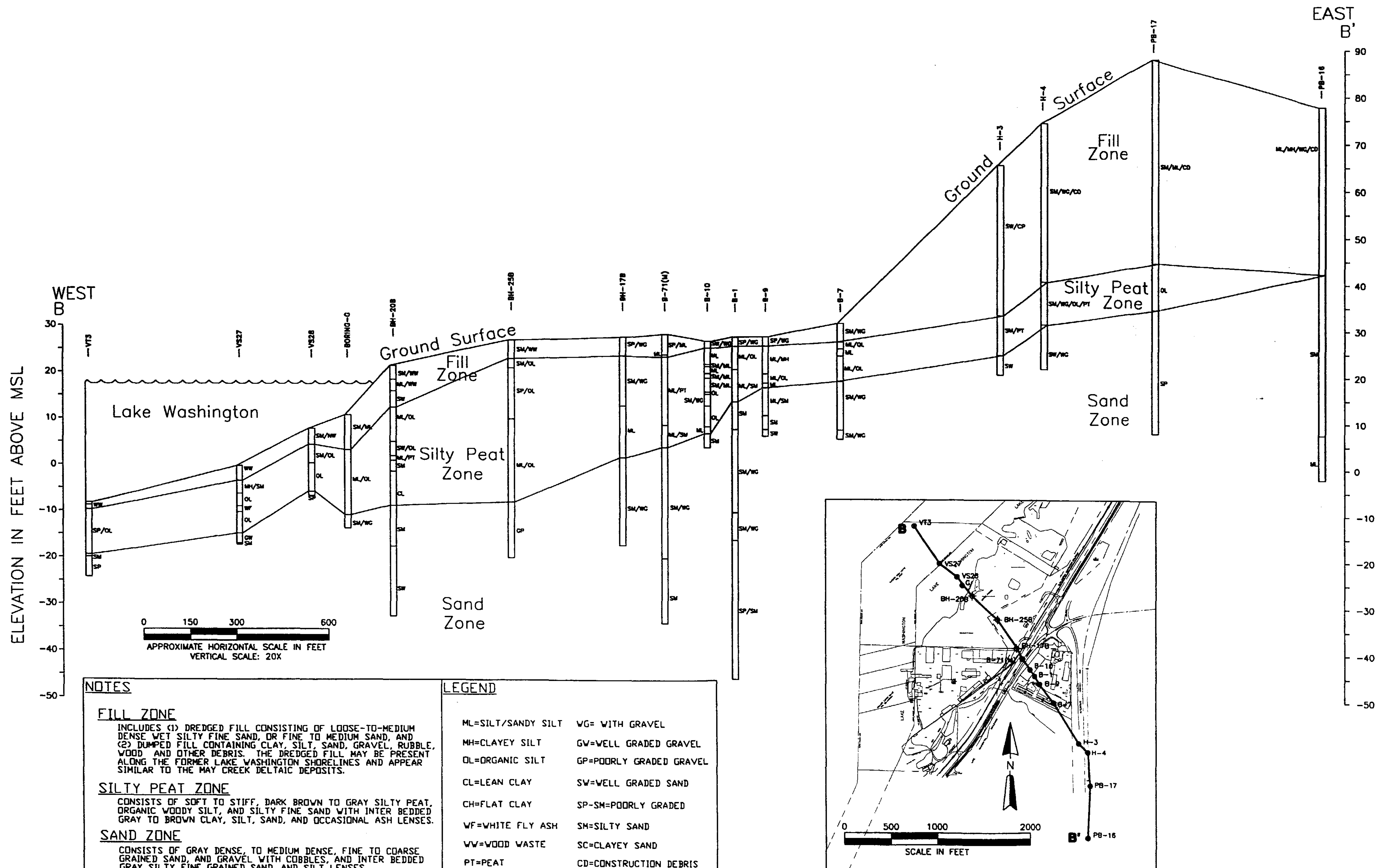

NOTES

FILL ZONE

INCLUDES (1) DREDGED FILL CONSISTING OF LOOSE-TO-MEDIUM DENSE WET SILTY FINE SAND, OR FINE TO MEDIUM SAND, AND (2) DUMPED FILL CONTAINING CLAY, SILT, SAND, GRAVEL, RUBBLE, WOOD AND OTHER DEBRIS. THE DREDGED FILL MAY BE PRESENT ALONG THE FORMER LAKE WASHINGTON SHORELINES AND APPEAR SIMILAR TO THE MAY CREEK DELTAIC DEPOSITS.

SILTY PEAT ZONE

CONSISTS OF SOFT TO STIFF, DARK BROWN TO GRAY SILTY PEAT, ORGANIC WOODY SILT, AND SILTY FINE SAND WITH INTER BEDDED GRAY TO BROWN CLAY, SILT, SAND, AND OCCASIONAL ASH LENSES.

SAND ZONE

CONSISTS OF GRAY DENSE, TO MEDIUM DENSE, FINE TO COARSE GRAINED SAND, AND GRAVEL WITH COBBLES, AND INTER BEDDED GRAY SILTY FINE GRAINED SAND, AND SILT LENSES.

LEGEND

ML=SILT/SANDY SILT	WG= WITH GRAVEL
MH=CLAYEY SILT	GW=WELL GRADED GRAVEL
OL=ORGANIC SILT	GP=POORLY GRADED GRAVEL
CL=LEAN CLAY	SW=WELL GRADED SAND
CH=FLAT CLAY	SP-SM=POORLY GRADED
WF=WHITE FLY ASH	SM=SILTY SAND
WW=WOOD WASTE	SC=CLAYEY SAND
PT=PEAT	CD=CONSTRUCTION DEBRIS

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PORT QUENDALL
EAST-WEST SITE
CROSS SECTION

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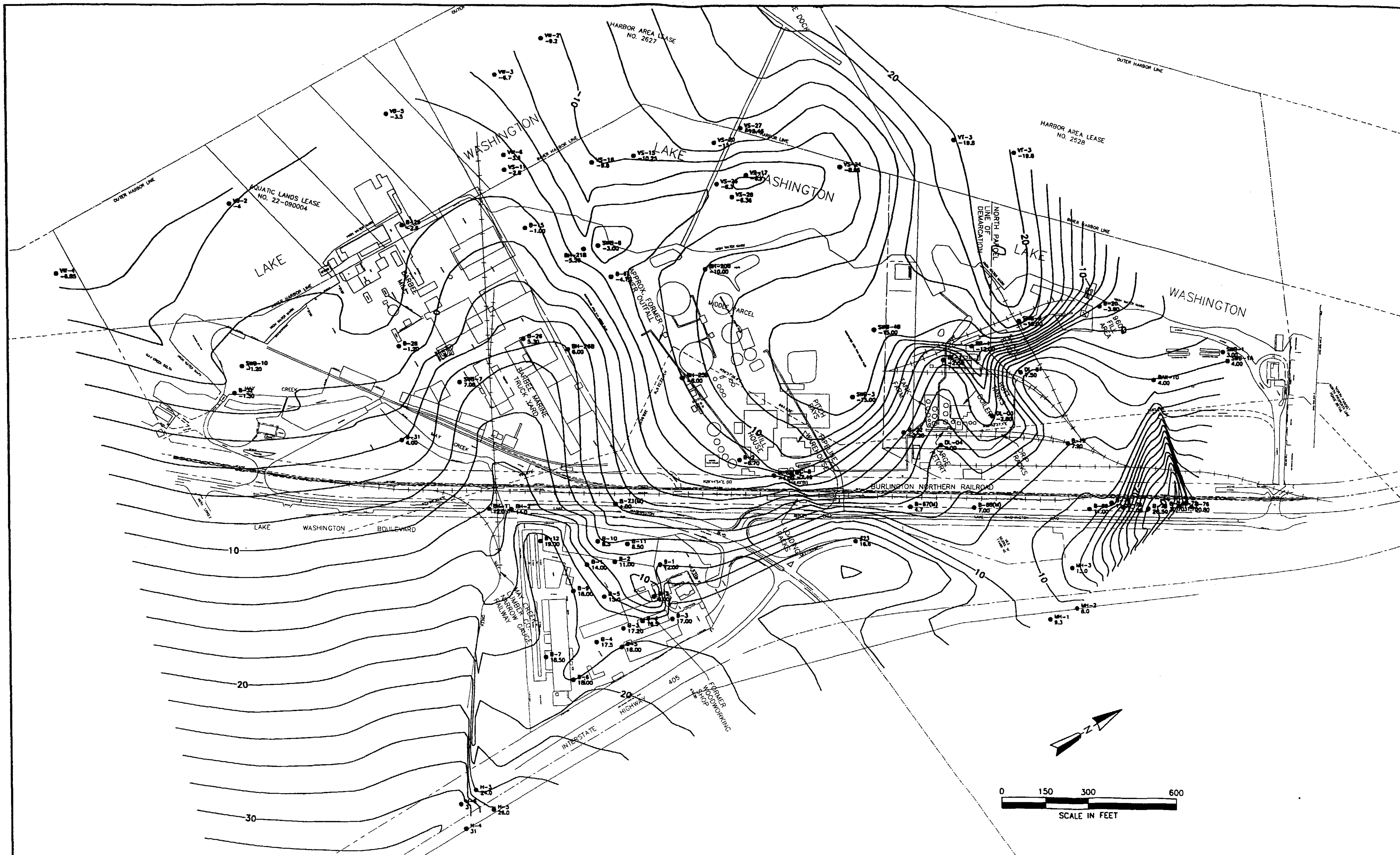

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TOP OF SAND ELEVATIONS
IN FEET ABOVE MSL

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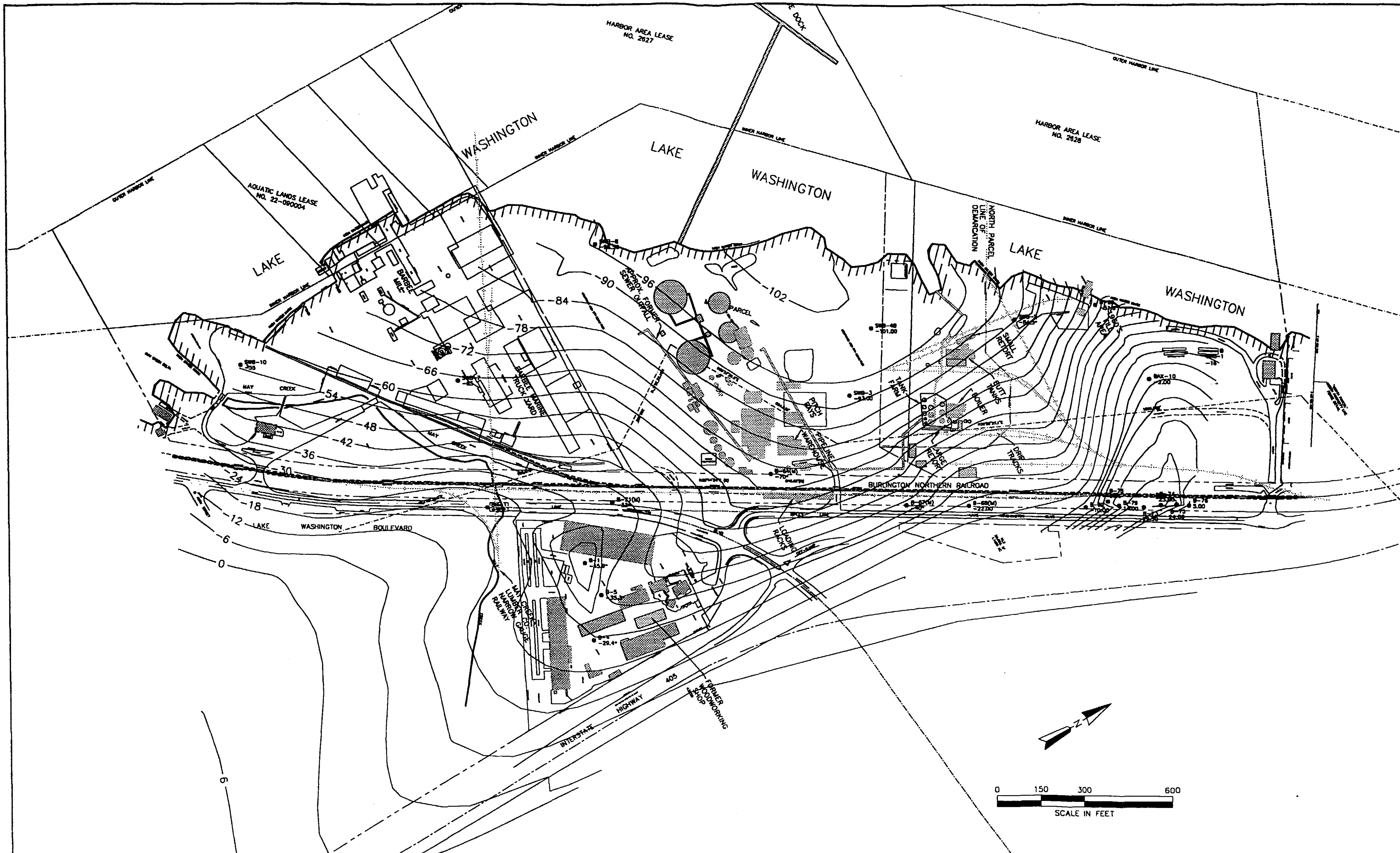

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BOTTOM OF SAND ELEVATIONS
IN FEET ABOVE MSL

RETEC
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of the silty peat layer is reflected in the large range of the estimated values. The lower estimates are associated with silt and clay lenses, whereas the higher values are associated with sand lenses. Six wells are screened over both the silty peat layer and a saturated portion of the fill zone; the conductivity estimates from these wells were analyzed as part of the silty peat zone. Table 2-1 is a summary of the available hydraulic conductivity estimates.

Two slug tests were completed in the sand layer and provide an estimated hydraulic conductivity of 5.7 ft/day and 56.7 ft/day.

2.2.2 Effective Porosity

Previous investigations have estimated the silty peat layer porosity between 0.28 and 0.32 (unitless) at the Baxter Property (Woodward Clyde Consultants, 1990) and 0.3 at the Quendall Terminals (Hart Crowser, 1996). Based on site data the effective porosity of the sand layer is estimated between 0.20 and 0.25 at both properties for modeling purposes.

2.3 Water Levels

Groundwater levels are relatively stable with seasonal variations of less than 2 feet in the sand zone and less than 3 feet in the silty peat layer. The groundwater level fluctuation in the sand zone appears to be dominated by the water level in Lake Washington, which is controlled to a consistent annual cycle by the Army Corps of Engineers. The water level fluctuation in the silty peat zone appears to be affected by both the seasonal precipitation trends and the controlled lake levels. The average shallow and deep water elevations are illustrated in Figures 2-5 and 2-6, respectively. Site groundwater and lake levels from recent and historical investigations are provided in Table 2-2. The data presented were compiled from past reports (Hart Crowser, 1996; Geo Consultants, 1992; Woodward-Clyde, 1990; CH_2M Hill, 1978) and RETEC groundwater sampling.

2.4 Conceptual Model

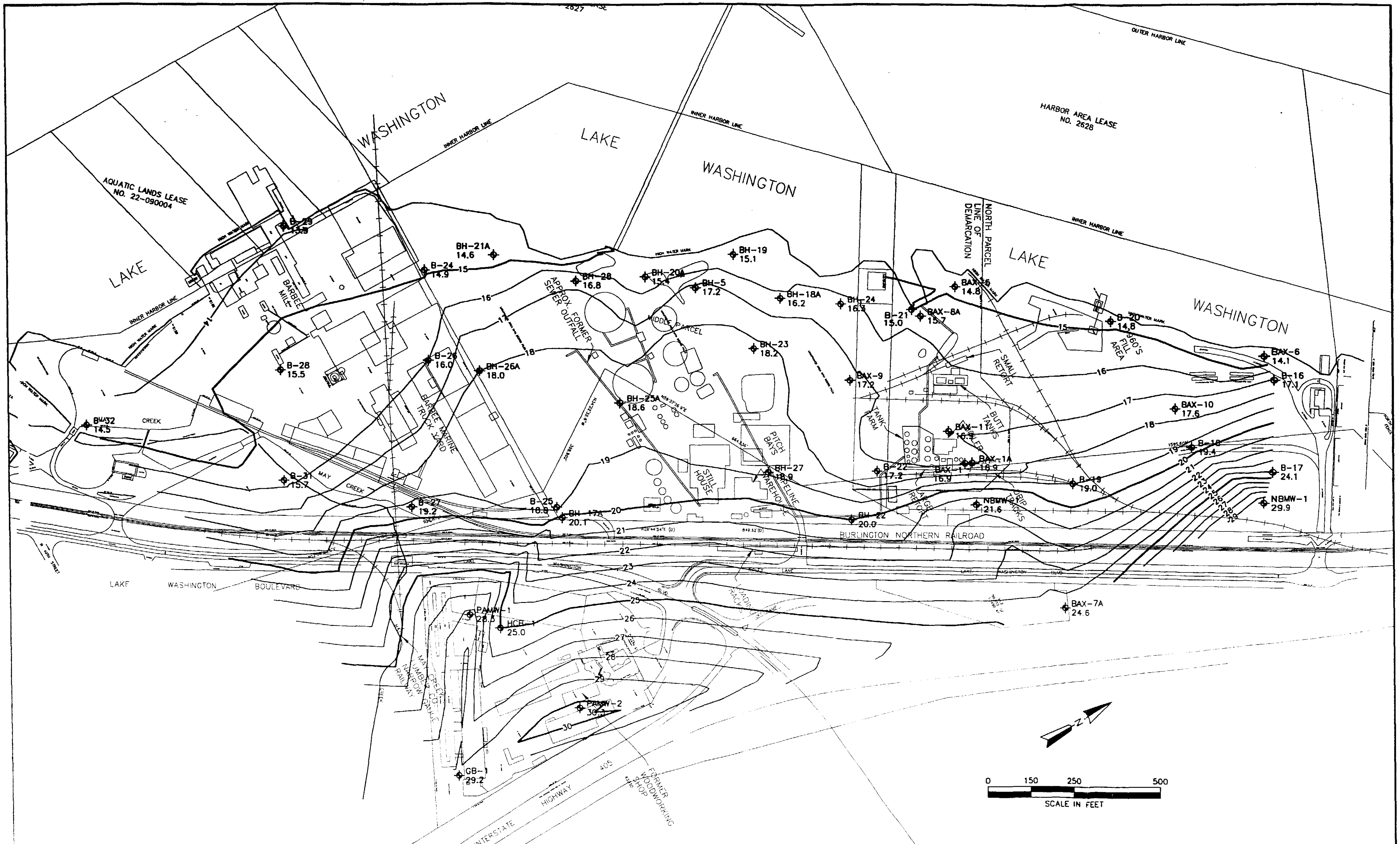
2.4.1 Model Area

The model area is characterized as the entire May Creek alluvial fan extending from the mouth of the May Creek Valley into Lake Washington bounded by the two bluffs to the south and east. Figure 2-7 illustrates the groundwater model area and includes ground surface and bathymetric elevation contours for reference. This corresponds to a model domain of approximately 4,900 ft by 6,200 ft.

Table 2-1 Hydraulic Conductivity Estimates Based on Pumping Test and Slug Tests

Test Location	Hydraulic Conductivity ft/day	Type of Test	Depth bgs of Screen Interval	Type of Soil in Screened Interval	Geologic Unit as Assigned by RETEC	Source
BAX-1A	2.1	slug test	5 to 20	silty sand	Fill and Silty Peat Zone	HC
BAX-5	0.6	slug test	8 to 18	silty sand and sand	Fill and Silty Peat Zone	HC
BAX-8A	15	slug test	10 to 20	sand	Silty Peat Zone	HC
BAX-9	31.2	pumping test	5 to 15	silty sand with silty and clay layer	Fill and Silty Peat Zone	WCC
BAX-10	1.5	slug test	10 to 20	sand and silty sand	Silty Peat Zone	HC
BH-10	3.4	pumping test	5 to 20	silty sand with layer of clayey silt	Fill and Silty Peat Zone	WCC
BH-15	4.8	pumping test	5 to 20	silty sand	Fill and Silty Peat Zone	WCC
BH-18A	0.6	slug test	4 to 14	silt	Fill and Silty Peat Zone	WCC
BH-2A	1.1	pumping test	? to 20	silty sand with peat interbeds	Silty Peat Zone	WCC
BH-6	8.8	pumping test	8 to 18	silty sand and silty clay with peat	Silty Peat Zone	WCC
BH-8	0.4	pumping test	13 to 23	silty clay with layer of silty sand	Silty Peat Zone	WCC
BH-19	15.6	pumping test	5 to 15	sand with layer of silt	Silty Peat Zone	WCC
BH-25A	6.8	pumping test	9 to 19	sand and silty sand with layer of silt	Silty Peat Zone	WCC
BH-12	2.2	slug test	13 to 23	sandy/clayey silt and very silty sand	Silty Peat Zone	WCC
BH-17A	0.2	slug test	6 to 16	sand to very silty sand with layer of silt	Silty Peat Zone	WCC
BH-19	17.0	slug test	5 to 15	sand with layer of silt	Silty Peat Zone	WCC
BH-20A	17.0	slug test	7 to 22	interbedded layer of silts	Silty Peat Zone	WCC
BH-23	0.2	slug test	7 to 22	silt with small layer of sand	Silty Peat Zone	WCC
WP-1	23.0	slug test	2 to 3(1)	sand	Silty Peat Zone	WCC
WP-4	0.5	slug test	2 to 3(1)	silt	Silty Peat Zone	WCC
WP-5	20.1	slug test	2 to 3(1)	sand	Silty Peat Zone	WCC
BH18B	56.7	slug test	42 to 52	sandy gravel	Sand Zone	WCC
BH-21B	5.7	slug test	42 to 52	gravelly f-m sand	Sand Zone	WCC

Notes:
1. Feet below mudline at offshore temporary well points.
HC = *Draft Remedial Investigation, Quendall Terminal Uplands*, Table 3-2, Hart Crowser Report, October 1, 1996
WCC = *Remedial Investigation Report, J.H. Baxter, Renton, Washington Site*, Vol 1, Woodward Clyde Consultants, October 1996



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AVERAGE SHALLOW WATER LEVELS
ELEVATIONS IN FEET ABOVE MSL

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REMEDIATION TECHNOLOGIES INC

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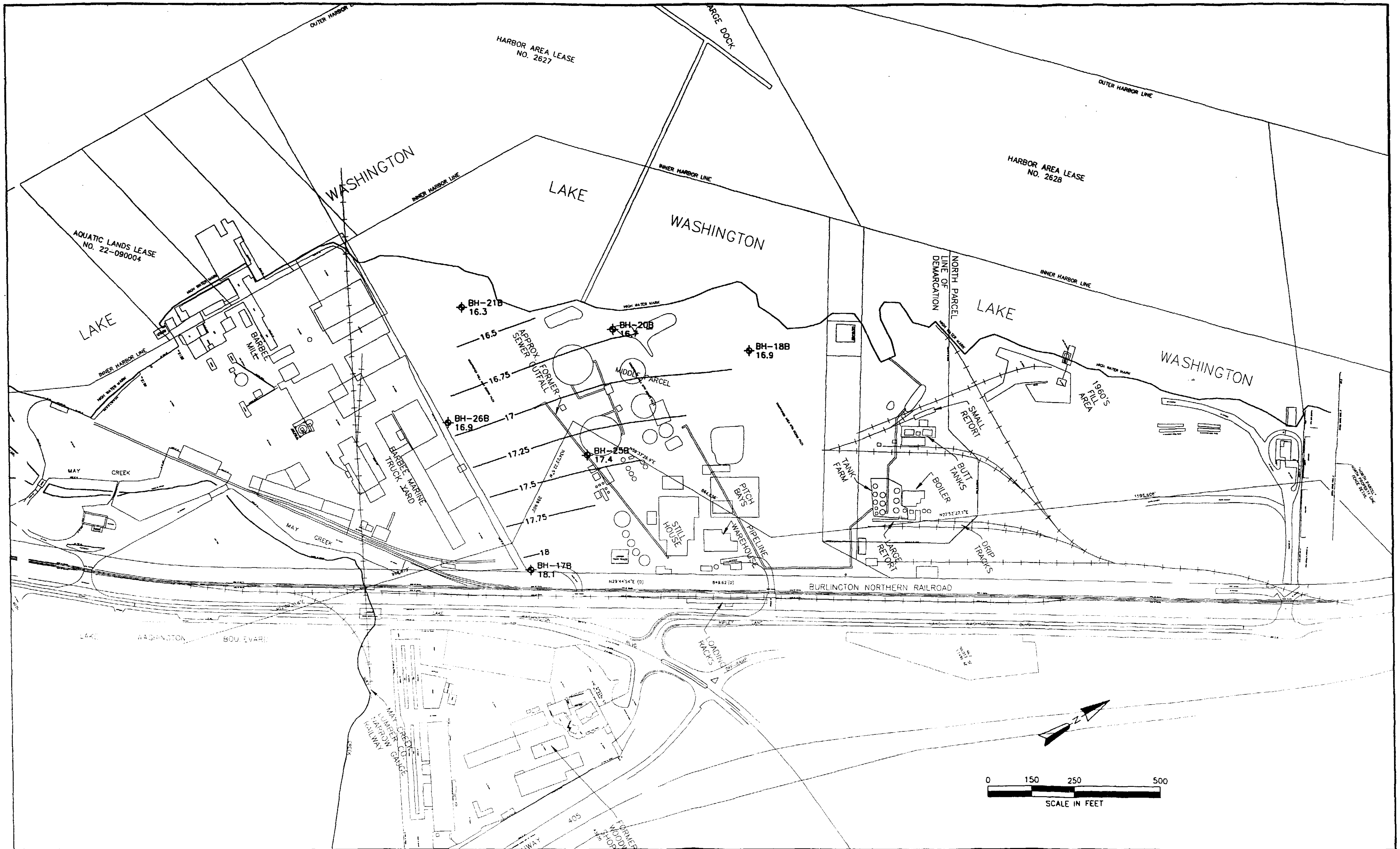

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DEEP WATER LEVELS
ELEVATIONS IN FEET ABOVE MSL

RETEC REMEDIATION TECHNOLOGIES INC

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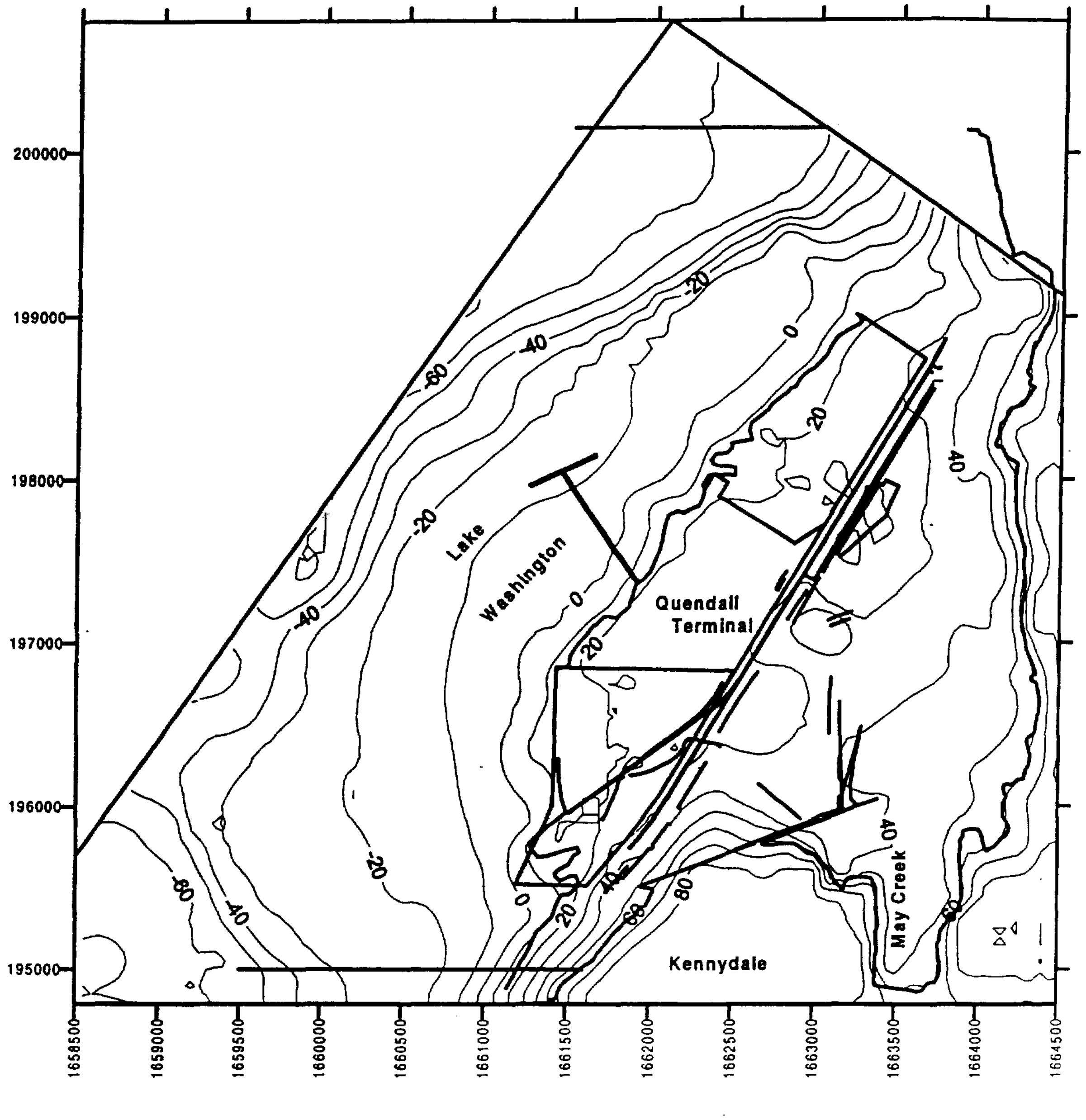
Table 2-2 Water Level Data

Well No.	Nov-78	Dec-78	Sep-85	Jan-89	Feb-89	Apr-89	Jun-89	Sep-89	Nov-89	Jan-90	Mar-90	Apr-91	May-91	Jun-91	Feb-92	Aug-95	Sep-95	Oct-95	Nov-95	Dec-95	Jan-96	Mar-96	Apr-96	May-96	Jun-96	Dec-96
Lake ACE				13.2	13.3	14.7	15.1	13.8	13.4	13.2	13.9	14.7	15.1	15.1		14.6	14.3	13.9	13.4	13.2	13.2	14.2	14.8	14.8	15.1	
B-16	16.9	17.2																								
B-17	24.0	24.2																								
B-18	19.6	19.1																								
B-19	18.6	19.3																								
B-20	14.8	14.7																								
B-21	14.7	15.3																								
B-22	17.0	17.3																								
B-24	15.1	14.7																								
B-25	18.8	18.7																								
B-26	16.1	15.9																								
B-27	19.2	19.2																								
B-28	15.1	15.9																								
B-29	13.9	13.8																								
B-31	15.3	16.0																								
B-32	14.6	14.3																								
B-1			22.8																							
B-3			22.8																							
BAX-1				16.8	16.6	17.3	17.1	16.2	16.7	17.2	17.2															
BAX-10				17.1	17.0	18.3	18.5	17.2	17.2	17.3	17.9															
BAX-11				16.8	16.6	17.5	17.4	16.1	17.0	16.7	17.2															
BAX-1A				16.7	16.6	17.5	17.3	16.3	16.6	17.1	17.3															
BAX-5				14.2	14.2	15.4	15.8	14.3	15.1	14.4	14.8															
BAX-6				13.7	13.6	14.9	15.2	14.0	13.8	13.6	14.3															
BAX-7A				24.7	24.5	25.7	25.1	23.1	23.7	25.0	25.1															
BAX-8A				15.4	15.3	16.2	16.6	15.4	15.5	15.5	15.9															
BAX-9				17.0	16.6	17.3	17.5	16.5	16.7	17.0	16.9	17.7	17.6			16.7		16.2		17.4	17.6		17.5	17.9	17.6	
BH-12				19.0	18.6	18.9		15.5	17.6	19.5	19.4		18.0													
BH-17A				19.5	20.1	21.2	20.0	19.0	19.2	20.5	20.7		20.5			19.0		18.9		21.6	21.0		20.3	20.6	20.2	
BH-17B				17.9	17.6	18.8	19.0	17.5	17.4	17.8	18.1					18.1		17.8		18.0	17.9		18.6	19.0	18.8	
BH-18A				16.9	15.9	16.2	16.2	14.8	16.0	16.0	16.5	14.6	16.4			15.2		16.0		17.3	17.4		17.2	17.5	16.1	
BH-18B				16.4	16.2	17.5	17.7	16.4	16.2	16.4	16.9					17.0		16.7		16.6	16.6		17.4	17.8	17.7	
BH-19				14.8	14.3	15.4	15.6	14.3	14.6	14.4	15.0	15.5	15.7			14.9		14.7		15.2	15.1		15.3	15.8	15.7	
BH-20A*				14.8	14.7	15.9	16.2	15.0	14.8	14.8	15.0		16.2			15.5		15.1		15.3	15.1		15.7	16.3	16.2	
BH-20B				16.2	16.0	17.2	17.4	16.2	16.0	16.2	16.7					16.8		16.5		16.3	16.3		17.1	17.6	17.5	
BH-21A*				14.1			15.6	12.1	14.1	14.1						15.0		14.6		14.5	14.6		15.3	15.8	15.7	
BH-21B				15.7	15.6	16.8	17.1	15.8	15.6	15.7	16.3					16.4		16.1		15.9	15.9		16.7	17.2	17.1	
BH-22				20.4		21.0	19.9	18.3	19.1	20.4	20.7			19.9												
BH-23*				18.6	17.4		24.5	16.4	17.1	17.6	19.0		18.2			16.5		16.1		18.9	18.7		18.0	18.5	18.0	
BH-24														16.5		15.6		15.6		16.7	16.7		16.5	16.8	16.4	
BH-25A*												19.1		18.5		17.8		17.4		18.9	18.9		18.8	19.1	18.9	
BH-25B													17.9	17.2			17.0		17.0	16.9		17.7	18.1	18.0		
BH-26A														17.8		17.0		17.2		18.9	18.6		18.0	18.4	17.8	
BH-26B													17.4	16.8			16.5		16.4	16.4		17.1	17.6	17.4		
BH-27														18.9		17.9		17.6		20.7			18.9		19.3	
BH-28																16.0		15.8		17.2	16.9			18.1	17.0	
BH-5*									20.3	20.5						15.6		15.3		16.7	16.6		16.4	16.8	16.6	
BH-5A*									14.6	14.5	14.6					16.0		15.6		19.7	19.8		19.2	19.2	18.5	
GB-1															29.2											
GB-2															22.7											
HCB-1															25.0											
NBMW-1																										21.6
NBMW-2																										29.9
PAMW-1																										28.3
PAMW-2																										30.3
SG-1																16.0		16.3		19.3	19.3		18.0	18.3	18.0	
SG-2																14.5		14.1		13.2	13.4		14.7	15.2	15.2	
SG-3																DRY		19.7		21.0	20.9		21.6	20.7	20.4	

Well No.	Max	Min	Average	Std Dev	# data pts	Source	Site
Lake ACE	15.1	13.2	14.1	0.7	21	Army Corps of Engineers database	
B-16	17.2	16.9	17.1	0.2	2	CH_2M Hill, 1978	Baxter
B-17	24.2	24.0	24.1	0.1	2	CH_2M Hill, 1978	Baxter
B-18	19.6	19.1	19.4	0.4	2	CH_2M Hill, 1978	Baxter
B-19	19.3	18.6	19.0	0.5	2	CH_2M Hill, 1978	Baxter
B-20	14.8	14.7	14.8	0.1	2	CH_2M Hill, 1978	Baxter
B-21	15.3	14.7	15.0	0.4	2	CH_2M Hill, 1978	Baxter
B-22	17.3	17.0	17.2	0.2	2	CH_2M Hill, 1978	Baxter
B-24	15.1	14.7	14.9	0.3	2	CH_2M Hill, 1978	Quendall
B-25	18.8	18.7	18.8	0.1	2	CH_2M Hill, 1978	Quendall
B-26	16.1	15.9	16.0	0.1	2	CH_2M Hill, 1978	Barbee Mills
B-27	19.2	19.2	19.2	0.0	2	CH_2M Hill, 1978	Barbee Mills
B-28	15.9	15.1	15.5	0.6	2	CH_2M Hill, 1978	Barbee Mills
B-29	13.9	13.8	13.9	0.1	2	CH_2M Hill, 1978	Barbee Mills
B-31	16.0	15.3	15.7	0.5	2	CH_2M Hill, 1978	Barbee Mills
B-32	14.6	14.3	14.5	0.2	2	CH_2M Hill, 1978	Barbee Mills
B-1	22.8	22.8	22.8	NA	1	Hart Crowser, 1985	Pan Abode
B-3	22.8	22.8	22.8	NA	1	Hart Crowser, 1985	Pan Abode
BAX-1	17.3	16.2	16.9	0.4	8	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Baxter
BAX-10	18.5	17.0	17.6	0.6	8	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Baxter
BAX-11	17.5	16.1	16.9	0.4	8	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Baxter
BAX-1A	17.5	16.3	16.9	0.4	8	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Baxter
BAX-5	15.8	14.2	14.8	0.6	8	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Baxter
BAX-6	15.2	13.6	14.1	0.6	8	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Baxter
BAX-7A	25.7	23.1	24.6	0.8	8	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Baxter
BAX-8A	16.6	15.3	15.7	0.5	8	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Baxter
BAX-9	17.9	16.2	17.2	0.5	17	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Baxter
BH-12	19.5	15.5	18.3	1.3	8	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-17A	21.6	18.9	20.1	0.8	16	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-17B	19.0	17.4	18.1	0.5	15	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-18A	17.5	14.6	16.2	0.8	17	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-18B	17.8	16.2	16.9	0.6	15	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-19	15.8	14.3	15.1	0.5	17	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-20A*	16.3	14.7	15.4	0.6	16	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-20B	17.6	16.0	16.7	0.6	15	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-21A*	15.8	12.1	14.6	1.0	12	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-21B	17.2	15.6	16.3	0.6	15	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-22	21.0	18.3	20.0	0.9	8	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-23*	24.5	16.1	18.2	2.0	15	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-24	16.8	15.6	16.3	0.5	8	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-25A*	19.1	17.4	18.6	0.6	9	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-25B	18.1	16.9	17.4	0.5	8	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-26A	18.9	17.0	18.0	0.7	8	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-26B	17.6	16.4	16.9	0.5	8	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-27	20.7	17.6	18.9	1.1	6	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-28	18.1	15.8	16.8	0.9	6	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-5*	20.5	15.3	17.2	1.9	9	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
BH-5A*	19.8	14.5	17.2	2.3	10	Hart Crowser , 1985 & 1996; Woodward Clyde , 1990 & 1996	Quendall
GB-1	29.2	29.2	29.2	NA	1	Geo Consultants, 1992	Pan Abode
GB-2	22.7	22.7	22.7	NA	1	Geo Consultants, 1992	Pan Abode
HCB-1	25.0	25.0	25.0	NA	1	Geo Consultants, 1992	Pan Abode
NBMW-1	21.6	21.6	21.6	NA	1	RETEC GW Sampling Log - JFG	Baxter
NBMW-2	29.9	29.9	29.9	NA	1	RETEC GW Sampling Log - JFG	Baxter
PAMW-1	28.3	28.3	28.3	NA	1	RETEC GW Sampling Log - JFG	Pan Abode
PAMW-2	30.3	30.3	30.3	NA	1	RETEC GW Sampling Log - JFG	Pan Abode
SG-1	19.3	16.0	17.9	1.3	7	Hart Crowser and Woodward Clyde Rpts	
SG-2	15.2	13.2	14.3	0.8	7	Hart Crowser and Woodward Clyde Rpts	
SG-3	21.6	19.7	20.7	0.6	6	Hart Crowser and Woodward Clyde Rpts	

1. TOC Elevation - Top of casing eleving in feet above mean sea level.
2. Elevation estimated from other measurements.
"---" - Well not found as of date indicated.
* - Indicates product has been observed in well.



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Ground-water model area and surface/bathymetric contours

2-7

2.4.2 Model Grid and Layers

The model domain was represented by a 4,900 ft by 6,240 ft model grid, with 60-foot spacing. A finer discretization of 30-foot grid spacing was used in select portions of the site to facilitate the simulation of potential remedial alternatives. The refined grid allows better simulation of the alternatives as well as increased groundwater flow resolution in these critical areas. Figure 2-8 illustrates the model grid.

Six layers were used to represent the hydrogeologic features of the model area and to assist in the modeling of remedial alternatives. The upper 1-foot high conductivity layer was used to model the boundary condition of the Lake Washington water level over the respective portion of the model. The second layer represented the silty peat zone. Figure 2-9 illustrates the modeled thickness of the silty peat layer. Layers three to six were used to model the sand zone. The sand zone was subdivided into the three layers to allow evaluation of various depths for the containment wall configurations. Figure 2-10 illustrates the thickness of the modeled sand layer.

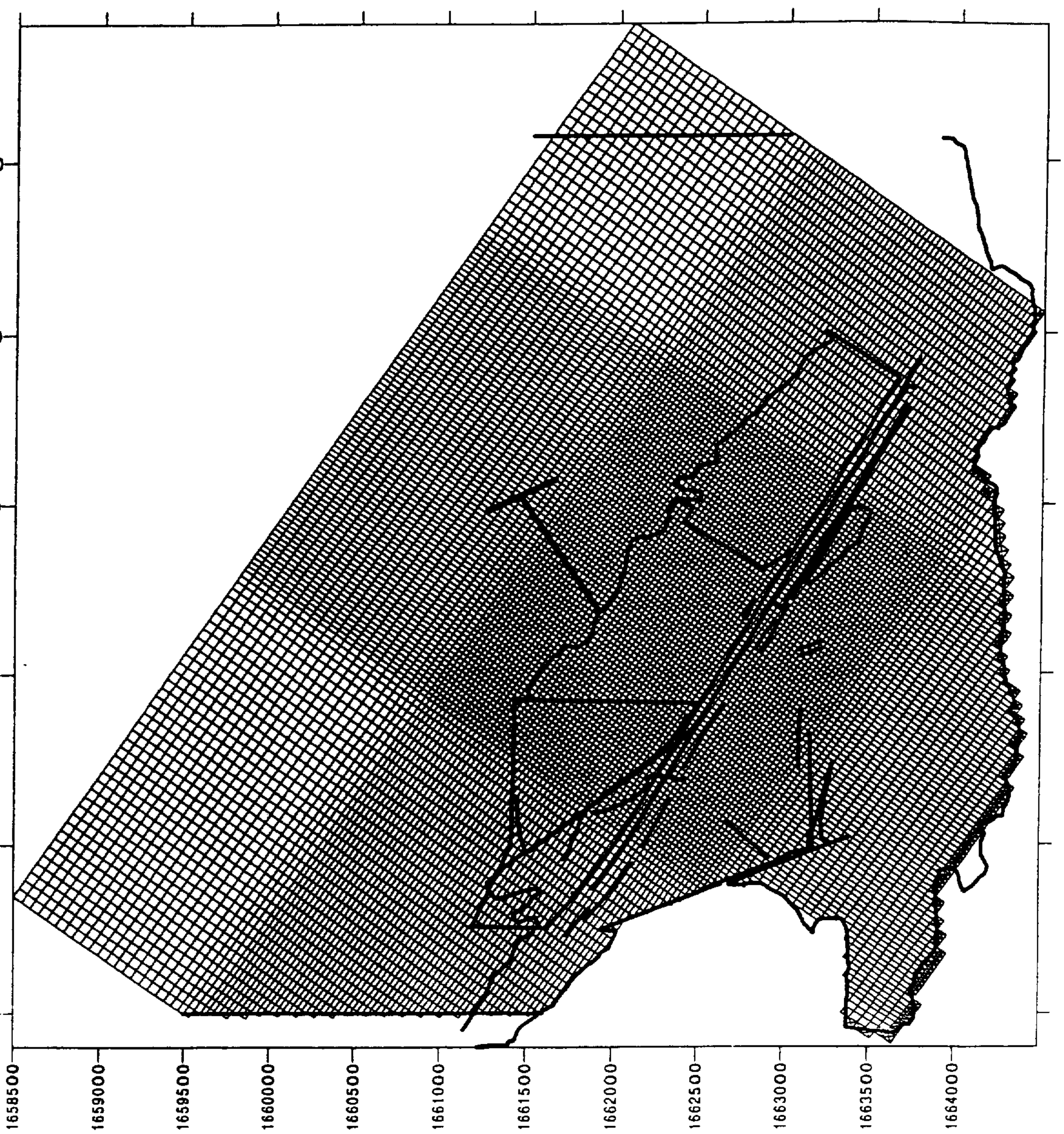
2.4.3 Boundary Conditions

Lake Washington is considered a constant head boundary given that the lake level is both stable and independent of site activity.

The location of the upland flow boundary is specific to each layer. The shallow silty peat layer extends to the toe of the bluffs east of Interstate 405 where shallow silty clays are encountered. It is anticipated that the silt and clay unit contributes little to groundwater flow and is therefore modeled as a no-flow boundary. The sand layers of the model are considered to be hydraulically connected to a regional aquifer beneath the toe of the bluffs. This regional aquifer is considered to be unaffected by site pumping activity and therefore a constant head boundary will be used for the east and south boundaries of the model.

2.4.4 Model Calibration

At the request of the Washington State Department of Ecology (Ecology), the model was calibrated to three sets of water levels: average water levels and two seasonal data sets. Water levels for the months of August 1995 and January 1996 were used to represent dry and wet season water levels, respectively.



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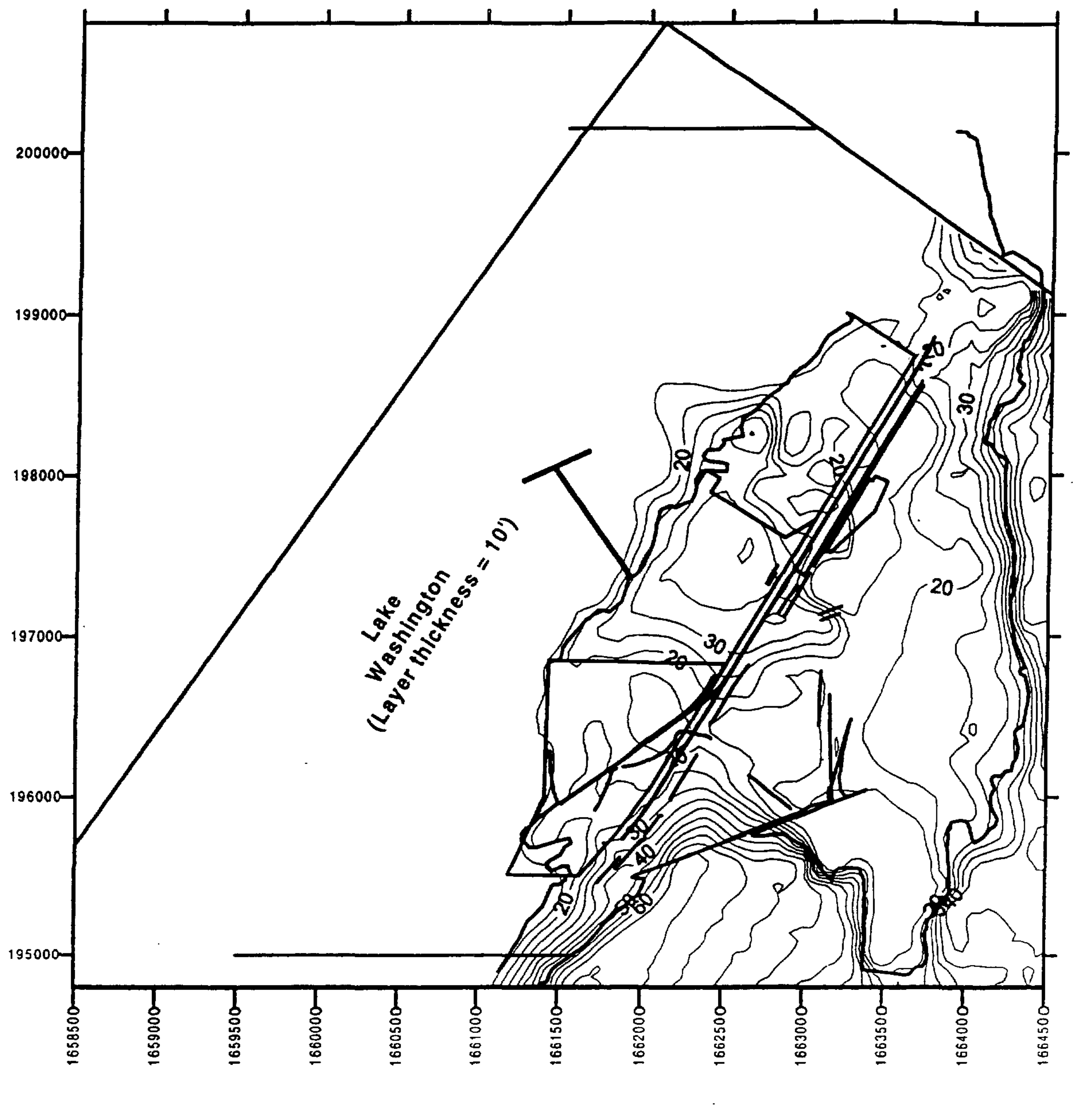
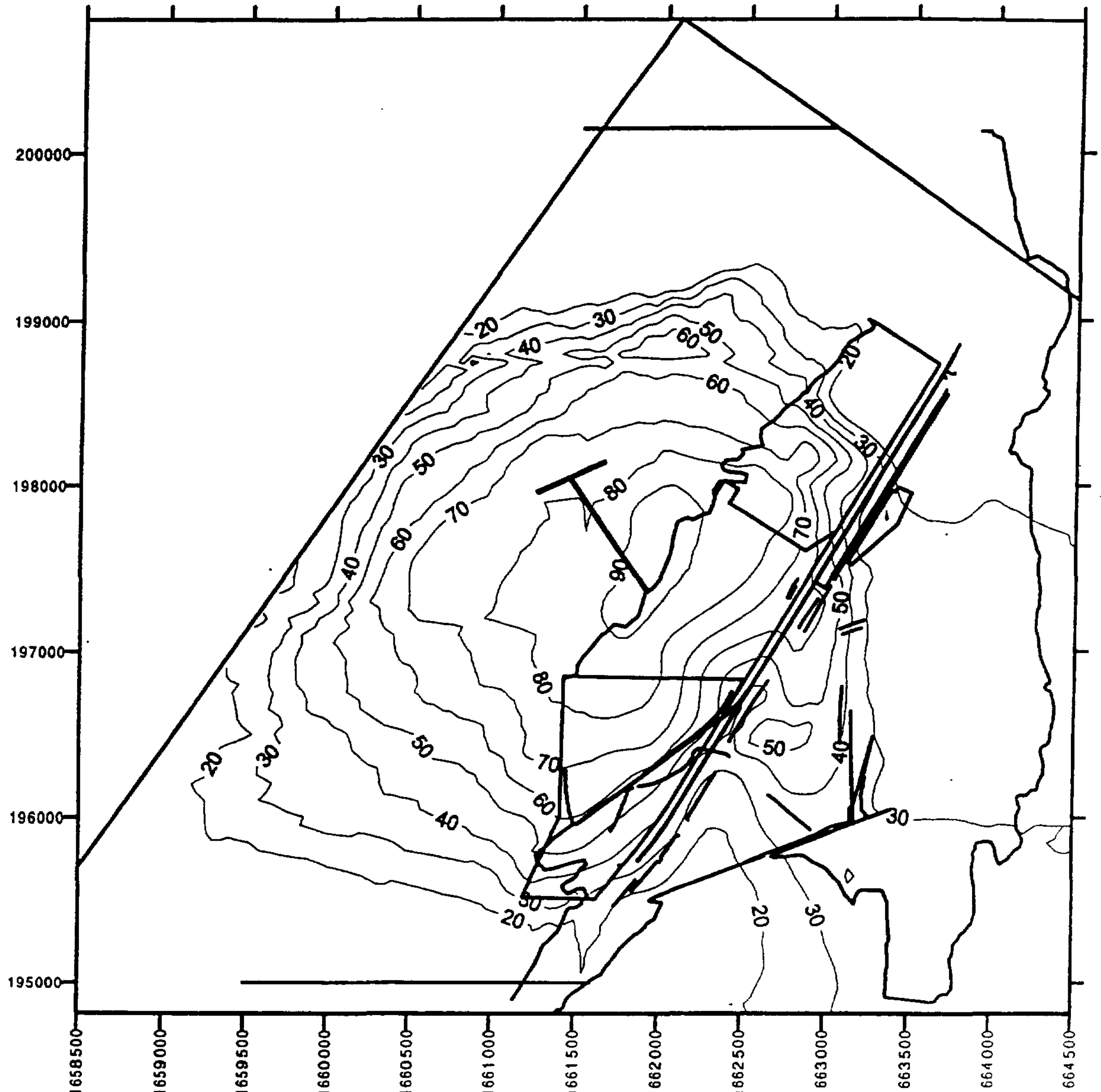
Model grid and boundary conditions
Hatched cells indicate constant head boundary

2-8



S.S. PAPADOPULOS & ASSOCIATES, INC. ENVIRONMENTAL & WATER-RESOURCE CONSULTANTS	**Model layer thickness for silt-peat layer**	2-9



$\Sigma^2\Pi$

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Model layer thickness for sand layer

2-10

The model was first calibrated to the January 1996 water levels by modifying the vertical and horizontal conductivity, recharge rate, and upland boundary conditions. The model was then calibrated using the August 1995 and average water levels by changing only the lake levels and the recharge rate. Calibration documentation is included in Appendix A10.

2.5 Discussion of Calibrated Model

The model parameters provided in Table 2-3 are used in the simulation of the remedial alternatives.

When comparing the model output to the average water level for several wells upgradient of the site, the model predicted lower water levels. This could be indicative of a localized perched water condition or lower hydraulic conductivity in the eastern portion of the model area. Recalibrating the model without changing boundary conditions to better represent these few wells would result in predictions of lower site hydraulic conductivity and therefore result in a less conservative model.

Table 2-3 Parameter Values for Calibrated Model

Calibration Parameter	Measured Range	Range Modeled	Calibrated Value	Values used in Previous Modeling[1]	Units
Horizontal Hydraulic Conductivity					
Silt-peat layer	0.2 to 17	1 to 4	3	0.3 and 15	feet/day
Lake sediments	0.5 to 23	8 to 25	20	NA	feet/day
Sand	6 to 57	25 to 70	40	60	feet/day
Vertical Hydraulic Conductivity					
Silt-peat layer	NA	0.02 to 0.21	0.06	0.03 to 0.15	feet/day
Lake sediments	NA	0.02 to 0.15	0.06	NA	feet/day
Sand	NA	0.4 to 4	4	6	feet/day
Upland Boundary Condition	NA	19 to 26	22.5	NA	feet MSL
Recharge	0 to 40	2 to 35	17, 22, 26[2]	0	inches/year

Notes:

1. Hart Crowser, Inc., 1996. *Draft Remedial Investigation, Quendall Terminals Upland, Renton, WA* .
2. August, calibrated average, and January recharge rates, respectively. The modeling presented in Section 3 of this report is based on the model calibrated to average water levels using 22" of rain per year.

NA - Not available or not applicable

3 Hydrogeologic Analysis

This section discusses the use of the calibrated model (presented in Section 2.4.4) to evaluate the containment wall alignments and configurations considered for the Port Quendall project area. The performance of each containment wall was evaluated by considering: pumping requirements for contaminated groundwater capture, particle tracking predictions, and an analysis of the barrier wall impacts on flow patterns. One remedial alternative, an aeration system, is not included in the hydrogeologic analysis because it would not affect flow patterns.

3.1 Description of the Containment Walls

Containment walls of varying depths and horizontal alignments were simulated and their performance was compared to the base case scenario. The base case scenario represents the present site condition modeled as the calibrated steady state model with no external stresses such as pumping.

A floating funnel and gate system was initially evaluated. However, because it did not provide adequate flow control, it was removed from further analysis. The different barrier wall configurations that were modeled are described below.

3.1.1 Containment Wall Depth

Two wall depths were considered in the Port Quendall FS. The shallow wall depth was considered the minimum depth required as a barrier against DNAPL seeps; it was modeled as a barrier extending approximately 30 to 35 ft bgs. The deeper wall was considered as a practical limit to containment wall construction; it was modeled as a barrier that extended approximately 50 ft bgs.

3.1.2 Containment Wall Horizontal Alignment

Three horizontal wall alignments were considered, one along the existing shoreline and two along the waterward edges of two fill areas as described in the Port Quendall FS (RETEC, 1997c). The fill areas were modeled as additional silty fill material, with hydrogeological properties identical to the upland silty peat zone. The extent of the wall was limited to the former Quendall Terminals property because this is the primary area of observed DNAPL contamination.

3.1.3 Conductivity of the Containment Wall

The proposed containment walls are 3 ft thick. To simulate this 3-foot wall within the 30-foot cells of the modeling grid, the effective horizontal conductivity was calculated using a harmonic mean. The harmonic mean was used to account for the dominance of the lower conductivity of the barrier wall despite its relatively small thickness.

The effective horizontal conductivity was calculated for a barrier wall within both the sand and silty fill units and no appreciable difference was noticed. Refer to Appendix A1 for the calculations of the representative conductivity. The vertical conductivity for these cells would not be appreciably affected, as vertical flow would occur relatively unimpeded, parallel to the wall (Freeze, 1979).

3.2 Procedures for the Hydrogeological Analysis

3.2.1 Capture Zone Analysis Procedures

Groundwater production wells can be used to capture contaminated groundwater. The extent of groundwater that will be captured by a well or set of wells is referred to as the capture zone. If a capture zone extends around all potential source areas, downgradient areas are protected. In the event that a groundwater point of exposure or point of compliance concentration is unacceptable, a system of wells can be used to intercept the contaminated groundwater.

To evaluate the containment wall configurations for capture zone analysis, a consistent set of eight extraction wells was used. The containment wall configurations can be evaluated in terms of the cumulative pumping extraction rate that is required to produce a capture zone that protects Lake Washington. The pumping rates associated with each containment wall configuration can be compared to the base case scenario to determine a relative remedial benefit. Lower cumulative pumping rates usually result in less contaminated water to be treated and require a smaller extraction system.

Preliminary modeling indicated that the most efficient well configuration places the extraction wells just upgradient of the containment wall.

The contaminated groundwater plume used in the analysis was created by superimposing the plumes of five chemicals that exceed MTCA method B surface water criteria. Benzene, chrysene, naphthalene, pentachlorophenol and benzo(a)pyrene were selected based on their toxicity and distribution at the site. These contaminants are used as representative constituents for modeling purposes. There are additional COCs which exceed surface water criteria.

Optimization of the eight extraction wells was based on evaluating the minimum pumping rate required to capture a set of particles placed around the perimeter of the superimposed indicator constituent of concern (ICOC) plume. The particles originated at a depth corresponding to the middle of the silty peat zone. Figure 3-1 illustrates the wall alignment for the upland wall scenario, the typical layout of the eight extraction wells, and the outline of the superimposed plume of the ICOCs.

3.2.2 Groundwater Travel Time Analysis Procedures

Groundwater travel times were evaluated from various source areas to the shoreline (APOC) and the groundwater discharge to surface water point (APOE). Particle travel times were evaluated using the particle tracking function of the MODPATH subroutine of MODFLOW. MODPATH determines the path line of a conservative tracer originating at a user defined source area with respect to time. A conservative tracer is a non-reactive particle that travels unretarded with the bulk groundwater flow.

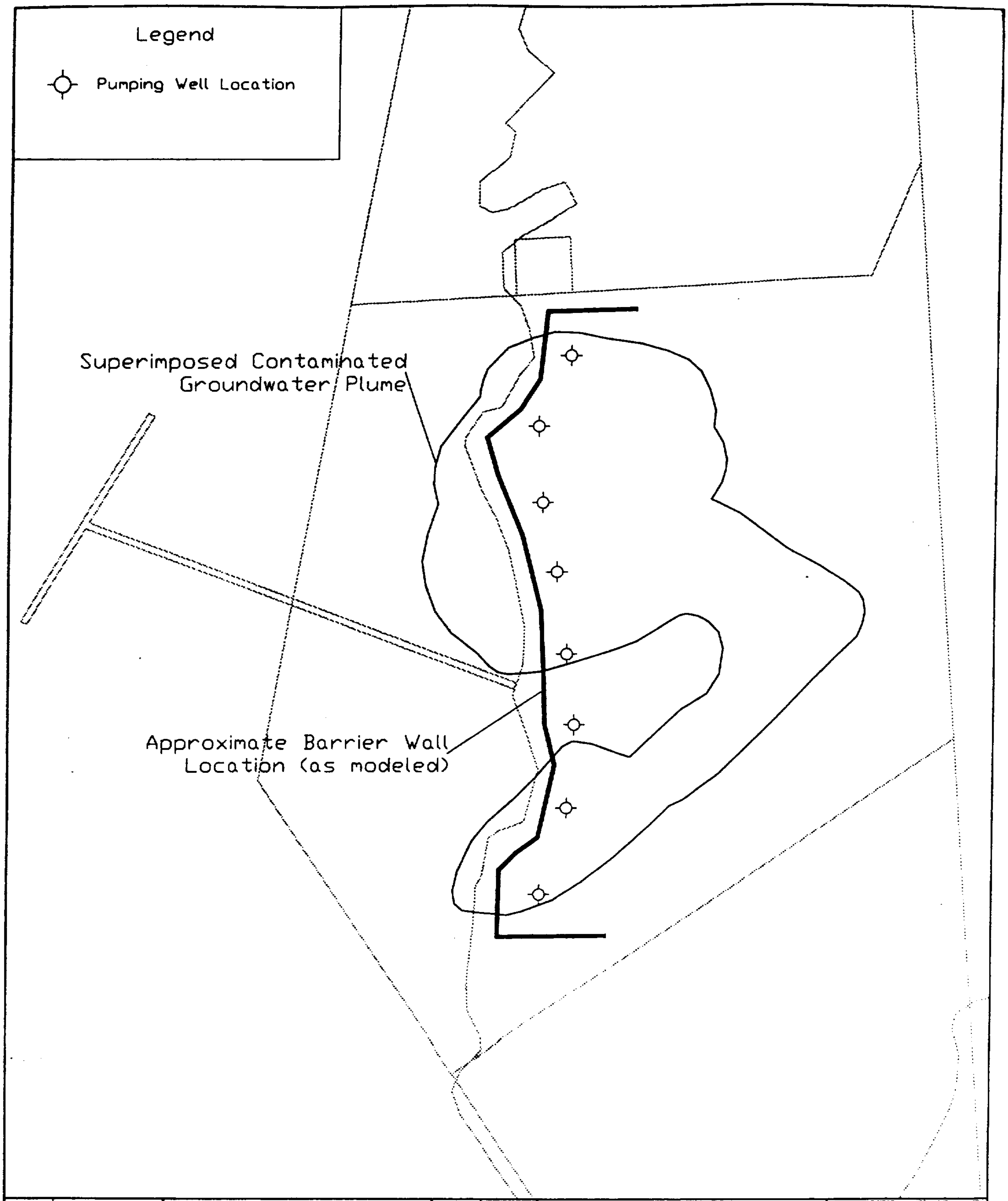
The effect containment wall configurations had on groundwater travel times from known source areas on site to either the APOC or the APOE were evaluated. The groundwater travel times associated with each containment wall configuration were compared to the base case scenario to determine a relative remedial benefit.

3.2.3 Groundwater Flow Pattern Analysis Procedures

All of the containment wall configurations are hanging walls as they are not keyed into a confining layer. The contaminated groundwater will travel beneath these hanging walls, but it is likely to converge to some restricted depth below the wall.

The dimensions of the zone through which the contaminated groundwater will travel can be used to design an aeration system. Theoretically, a smaller zone of converged contaminated groundwater flow is a remedial benefit, as it will require a smaller zone of aeration.

The zone of convergence of contaminated groundwater can be characterized by distributing a representative conservative tracer around the perimeter of the superimposed plume of ICOCs and observing the predicted particle path lines beneath the north, central and south segments of the containment wall. The zone of convergence of contaminated flow is the area extending from the bottom of the wall to the deepest path line below the wall. This zone is defined by the particles originating at the upgradient side of the groundwater plume.



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NO | DRWN | DATE | REVISION | CHKD | DATE | APPVD | DATE

3-2438-612

SCALE NONE

CAD FILE 2438S212

SUPERIMPOSED CONTAMINATED GROUNDWATER PLUME

RETEC
REMEDIATION TECHNOLOGIES INC

DRAWING NO. FIGURE 3-1 REV. 0

3.3 Results of the Hydrogeological Analysis

3.3.1 Capture Zone Analysis Results

The cumulative pumping rates required for capture of particles located around the perimeter of the superimposed groundwater plume are presented in detail in Appendix A2 and summarized in Table 3-1. The pumping rates associated with each alternative were compared to the base case pumping rate required for capture. The base case is defined as the flow regime as it exists with no barrier wall. Smaller cumulative pumping rates are a significant remedial benefit given the financial savings associated with smaller pump and treat systems and smaller volumes of contaminated water to treat.

Table 3-1 Groundwater Extraction Rates Required for Contaminated Plume Capture

Simulated Alternative	Depth of Wall (ft)	Pumping Rate Required for Capture (GPM)	Alignment of Wells
Base case	NA	145.6	along shore
Upland Wall	30	44.2	along shore
Upland Wall	50	26	along shore
Nearshore	30	37.7	along shore/fill
Nearshore	50	23.4	along shore/fill
Nearshore CDF Wall	30	35.1	along shore/fill
Nearshore CDF Wall	50	19.5	along shore/fill

As anticipated, the deeper nearshore confined disposal facility (CDF) wall results in the lowest required pumping rate of 19.5 gallons per minute (gpm), which is 13 percent of the base case pumping rate. The pumping rates were more sensitive to wall depth, with the 50-foot walls significantly outperforming the 30-foot walls. The nearshore walls marginally outperformed the upland walls.

The containment wall configurations tested resulted in cumulative pumping rates that range from 13 to 30 percent of the base case.

3.3.2 Groundwater Travel Time Analysis Results

A conservative tracer represents the flow of the water through porous media, ignoring any retardation effects that the ICOCs would experience. While this approach does not directly predict the travel times for the ICOCs, these travel times can be evaluated on a relative basis. An alternative that results in longer travels times to the APOE provides contaminants more time to attenuate. The longer travel time is also indicative of a longer pathway; this can be confirmed when reviewing the particle tracking output. Longer contaminant pathways result in greater attenuation due to increased diffusion and dispersion.

The particle travel time from the four source areas to the APOC and APOE is presented in detail in Appendix A3 and summarized in Table 3-2. These travel times were compared to the base case to evaluate the increase in travel time. For example, the upland shallow wall alternative results in a particle travel time that is roughly 200 percent longer (1,200 days compared to base case of 600 days) than the base case travel time for a particle that originates at the nearshore source areas.

Table 3-2 Travel Times from Source to APOC and APOE for various Containment Wall Configurations

Simulated Alternative	Wall Depth (ft)	Farshore Areas				Nearshore Areas			
		North Sump		Still House		Quendall Pond		May Creek	
		APOC (days)	APOE (days)	APOC (days)	APOE (days)	APOC (days)	APOE (days)	APOC (days)	APOE (days)
Base case	NA	2120	2740	1740	2400	140	600	280	600
Upland wall	30	1600	2400	1740	2440	200	1280	600	1200
Upland wall	50	1780	2900	1960	3000	700	2040	600	1800
Nearshore	30	1600	2420	1760	2480	540	1300	600	1160
Nearshore	50	1800	2820	1940	2940	920	1680	760	1580
Nearshore CDF	30	1680	2440	2160	3000	1120	1640	530	1080
Nearshore CDF	50	1880	2800	2240	3040	1240	2200	900	1720

Notes: APOC - Assumed Point of Compliance
APOE - Assumed Point of Exposure

The containment wall configurations tested result in travel times that range from 88 to 367 percent of the base case travel times to the APOE. Typically the travel times increased, however the travel times of particles originating in one of four source areas decreased when a wall was simulated. This was likely a result of localized increased groundwater velocity associated with the walls.

3.3.3 Groundwater Flow Pattern Analysis Results

Modeling indicates that groundwater converges under the wall. As observed in the particle tracking output, the contaminated flow that originates at the east portion of the site travels the farthest below the walls. These particle pathways delineate a vertical zone of convergence that could be targeted with air sparging points for accelerated degradation. A schematic of the zone of convergence is presented in Figure 3-2.

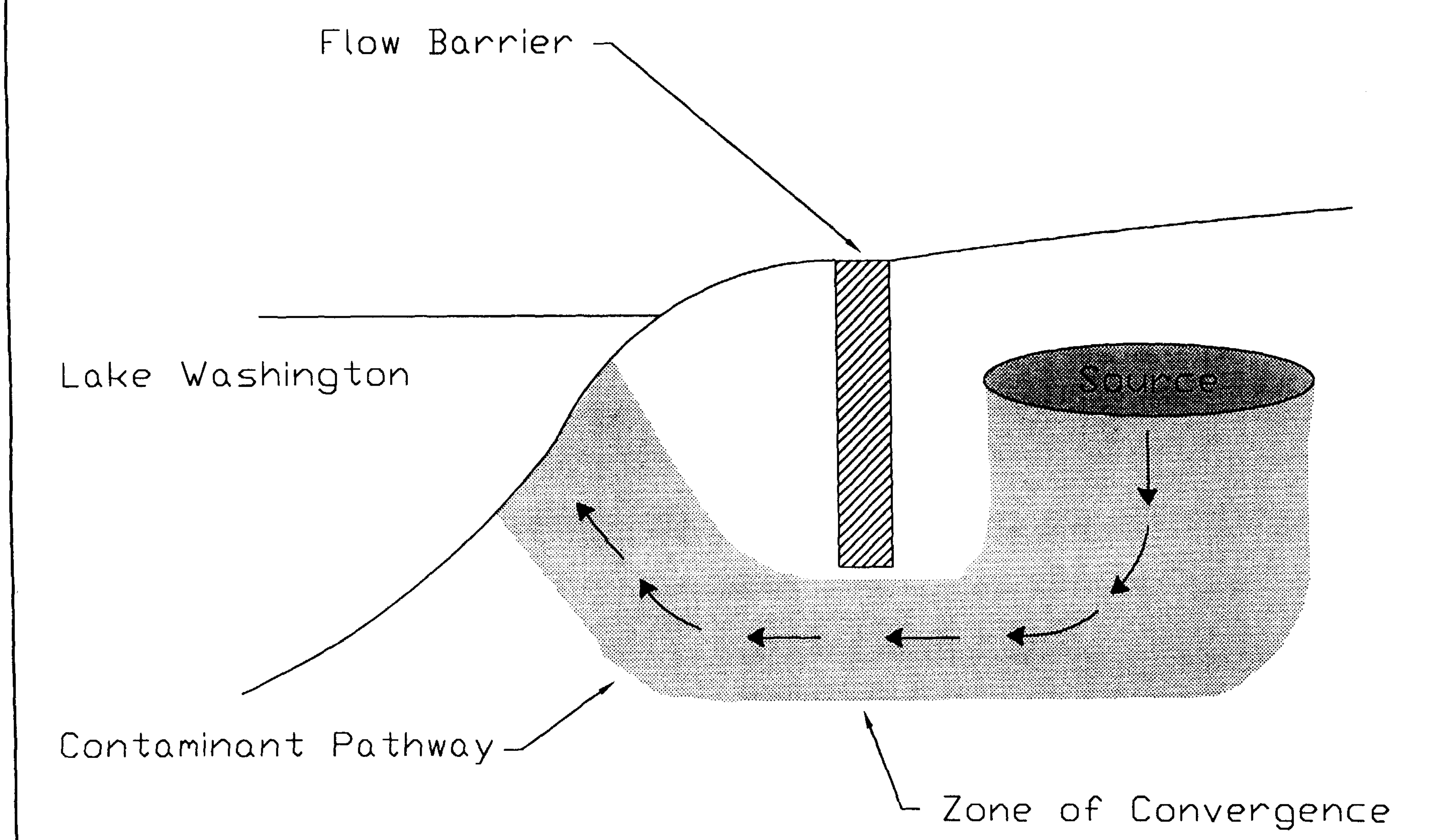
This zone of convergence was characterized at the north, central and south segments of the wall. The predicted depth of the zone of convergence in these three locations is presented in Appendix A3. The flow velocity was also estimated based on residence time and the horizontal length (flow direction). The flow was estimated to converge in a zone that has greater depth in the center of the wall and ranges from 15 to 28 ft, with flow velocities that range from 0.27 to 0.6 ft/day.

3.4 Dewatering Analysis

As part of the feasibility study, several source removal actions are being evaluated. These excavation zones extend below the water table and therefore an approximation of the pumping rates required to dewater these areas is required.

The zone budget subroutine of MODFLOW was used to determine the necessary pumping rate required to achieve a defined local water table elevation. This local water table elevation was set as the elevation of the bottom of the excavation to determine the required dewatering rate. The excavation dewatering pumping rates are estimated for the Baxter Nearshore Process Area, Quendall Pond and May Creek DNAPL source areas. These pumping rates are determined for two scenarios: with and without a temporary flow barrier. Table 3-3 summarizes the pumping rates.

Appendix A7 presents the detailed results of the dewatering analysis. A sensitivity analysis revealed that the relationship of the required dewatering rate to the conductivity of the silty peat zone is roughly linear: an increase of 10 percent of the conductivity would result in a 10 percent greater dewatering pumping rate.



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Fate and Transport Schematic Illustrating the Zone of Convergence

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Table 3-3 Dewatering Rates Required for Source Removal

Area to be Dewatered	Pumping Rate (GPM)	
	Without a Flow Barrier	With a Flow Barrier
Baxter Nearshore Process Area	40	26
Farshore Process Area	10	NA
North Sump Farshore	34	NA
Quendall Pond Nearshore	82	24
Still House Farshore	25	NA
May Creek Nearshore	67	32

4 Fate and Transport Modeling

This section presents a general overview of the fate and transport modeling that was performed to support the Port Quendall FS (RETEC, 1997c). The fate and transport modeling described in this section investigated the model's sensitivity to the different parameters and the effect of the various proposed remedial actions. These results were used to evaluate a more focused set of remedial alternatives presented in the FS as discussed in Section 5 of this report.

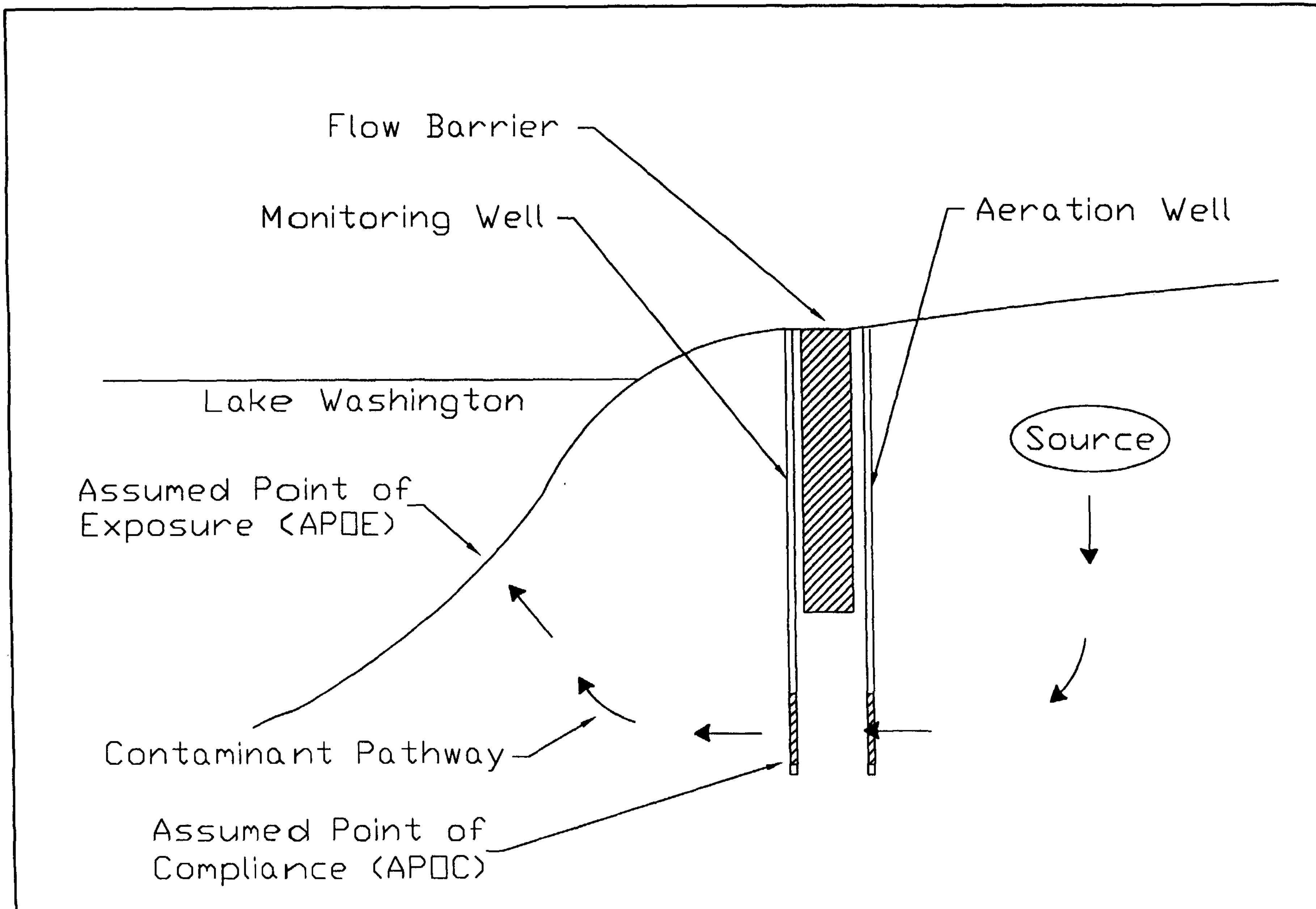
4.1 Fate and Transport Overview

A fate and transport analysis was used to estimate the source concentrations that attenuate to MTCA Method B Surface Water Criteria for various remedial action scenarios. The fate and transport modeling was a simplified one-dimensional representation of particles of benzene, naphthalene, and chrysene that originate in two representative source areas. These constituents were used as indicator constituents for fate and transport modeling purposes (RETEC, 1997a). An analytical contaminant transport model based on the Domenico solution (Domenico, 1987) is used to estimate the attenuation of the indicator constituents between the shoreline (APOC) and the point of groundwater discharge to surface water (APOE). The Domenico solution accounts for the changes in contaminant concentration as groundwater flows from the source areas to a APOC or a APOE. Figure 4-1 schematically illustrates the fate and transport modeling assumptions.

The fate and transport modeling was performed for three different degradation rates. No degradation was also modeled to conservatively simulate natural attenuation. The degradation rates were based on treatability study results and literature values.

The Domenico model predicts the maximum centerline groundwater concentration in a contaminant plume under steady-state conditions assuming:

- Uniform and constant aquifer properties
- One-dimensional groundwater flow
- First-order contaminant decay, degradation, or transformation
- A constant contaminant source, rectangular in cross section, in the plane perpendicular to groundwater flow



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Fate and Transport Schematic

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Seattle, WA

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Several simplifying assumptions are necessary to simulate the three-dimensional heterogeneous flow regime with the one-dimensional model. Particles originating in the source areas will travel through three distinct zones: the silty peat zone, the sand zone, and the lake sediment. Parameters were selected to conservatively represent the hydrogeology of the heterogeneous site based on an assumed average path line through the various hydrogeological units.

To evaluate the fate and transport of the three ICOCs, two potential remedial cases were evaluated: the shallow upland wall and the shallow nearshore CDF wall. These cases are unique in terms of the critical source area (the source area that results in the shortest pathway to the APOE). For the shallow upland wall alternative, the critical source area is the Quendall Pond Nearshore Source Area. For the shallow nearshore CDF wall alternative, the critical source area is the May Creek Nearshore Source Area.

Within the groundwater flow regime, the model accounted for the effects of advection, dispersion, sorption, and biodegradation. For a given source area concentration, the model predicts steady-state plume concentrations at any point in the downgradient flow system. The model predicted the maximum centerline groundwater concentration in a dissolved plume at any downgradient distance x (i.e., the receptor location), based on one-dimensional adjective flow and three-dimensional dispersion. Complete model documentation is provided in Appendix A4.

4.2 Input Parameters

4.2.1 Groundwater Source Term

The modeling presented in this section determines a source concentration that will result in an APOE concentration that is below the MTCA Method B Surface Water Criteria. To calculate the concentration, the dimensions of this source are required as input. The Domenico solution represents the groundwater source as a vertical plane, perpendicular to groundwater flow, that releases dissolved constituents into groundwater passing through it. The source was assumed to be infinite and constant with respect to time. The source was assumed to be located at the APOC.

To provide perspective on the predicted groundwater concentrations at the APOC which will attenuate below Method B surface water standards at the APOE, three source concentrations are presented in Table 4-1 for each ICOC: the solubility limit, the product leachate concentration and the matrix leachate concentration. These concentrations are determined as follows:

Solubility Limit: The solubility limit represents the concentration of pure ICOC, present in excess, that would dissolved into pure water at 20°C (American Society for Testing and Materials (ASTM)).

Product Leachate Concentration: Free product was dissolved into groundwater taken from the site and the saturated sample was then analyzed for the concentration of a particular dissolved ICOC to determine the product leachate concentration.

Matrix Leachate Concentration: Saturated soil samples were immersed in groundwater and allowed to partition. The saturated groundwater sample was then analyzed for the concentration of a particular dissolved ICOC to determine the matrix leachate concentration.

Table 4-1 Evaluation of Potential Assumed Source Concentrations

	Solubility Limit mg/L	Product Leachate Concentration mg/L	Matrix Leachate Concentration mg/L	Maximum Shoreline Concentration mg/L
Benzene	1750.0	16.5	1.5	WP4: 0.14
Chrysene	0.0060	Chrysene is undetectable in lab studies	Chrysene is undetectable in lab studies	WP2: 0.0002
Naphthalene	32.90	8.2	2.6	WP3: 11.0

Note: Method B Surface Water Limit: MTCA Method B Surface Water Limits taken from the CLARC II Database - February 1996. Washington Department of Ecology.

***Solubility Limit*:** This is the solubility limit of the ICOC at 20-25°C as published by ASTM

4.2.2 Flow and Mixing Parameters

The degree of contaminant mixing predicted by the model is a function of dispersion coefficients, hydraulic conductivity, hydraulic flow gradient, and effective soil porosity. Conservative default dispersivity coefficients specified in the model were used to evaluate dispersion. For purposes of fate and transport modeling, representative hydraulic parameters were calculated by averaging the calibrated values for the three zones (fill, sand and lake sediment). The representative parameter values are calculated in Appendix A5 and are summarized below.

Hydraulic Conductivity	17.2 ft/Day
Effective Porosity	0.25
Groundwater Gradient	0.0069 ft/ft

4.2.3 First-Order Decay Parameters

Under steady-state conditions, hydrolysis and biodegradation represent the principal mechanisms of organic contaminant mass reduction during groundwater plume transport. For the scenarios without an aeration system, no decay was assumed and, therefore, the contaminant decay term in the model was set equal to zero.

For the scenarios that represent a functioning aeration system, degradation rates were selected based on treatability studies (RETEC, 1997d) and published literature values. Three degradation rates were evaluated: 1 and 10 percent of the degradation rate achieved in the lab study, and the lowest available literature value. Refer to Table 4-2 for three degradation rates used in this evaluation. The treatability results for pyrene were substituted for chrysene given chrysene's non-detect results. This substitution is justified given: 1) the similar structure of chrysene and pyrene; and 2) their literature degradation values are very similar (see Appendix A5). The literature and laboratory degradation rates of chrysene, benzene and naphthalene are presented in Appendix A5. The model runs become more conservative as the degradation rates approach zero. The basis for a non-zero degradation rate is as follows:

Lab Rate * 0.1: This is one order of magnitude lower than the aerobic unamended (with nutrients) degradation rates that were calculated in the Port Quendall treatability study (RETEC, 1997d).

Lab Rate * 0.01: This is two orders of magnitude lower than the aerobic unamended (with nutrients) degradation rates that were calculated in the Port Quendall treatability study (RETEC, 1997d).

Low Literature Value: This is the lower limit aerobic degradation rate published in the "Handbook of Environmental Degradation Rates" (Howard, *et al*, 1991).

The aeration scenarios were particularly conservative because degradation was assumed to take place along the path length following the treatment zone. Therefore, the scenarios did not account for the attenuation and dispersion that would occur between the source and the treatment zone.

Table 4-2 Degradation Rates Used in Fate and Transport Analysis

	1/10 Lab Rate	1/100 Lab Rate	Low Literature Value
Benzene	0.535	0.0535	0.043
Chrysene	0.0549	0.00549	0.0007
Naphthalene	0.516	0.0516	0.035

Notes:
--The benzene and naphthalene degradation lab rates are based on the column study as presented in the treatability study (RETEC, 1997d).
--The chrysene lab rates are based on the pyrene aerobic respirometry study as presented in the treatability study (RETEC, 1997d).
--The literature rates are taken from the *Handbook of Environmental Degradation Rates* (Howard, 1991).

4.2.4 Retardation Factors

The rate at which a plume moves may be reduced by constituent sorption to solids or organic matter in the subsurface. The retardation factor for each ICOC was calculated using the chemical-specific organic-carbon partition coefficient (K_{oc}) and a fraction of organic carbon (f_{oc}) equal to 0.22 percent (Hart Crowser, 1996). Literature K_{oc} values were used for the three ICOCs (Appendix A5).

4.2.5 Distance to Receptor

Using the input parameters specified above, the model can back calculate the allowable source concentration based on a given receptor distance and a target concentration (e.g., cleanup criteria). The distance to the receptor (i.e., Lake Washington) was determined as part of the particle tracking analysis performed using the MODPATH module of MODFLOW. Appendix A5 summarizes the particle tracking results and provides the distances to the lake used in the model for the shallow upland and nearshore CDF walls.

4.3 Results of the Fate and Transport Analysis

Appendix A6 presents the fate and transport simulation runs as a function of degradation rate and source concentration. Results are expressed as concentrations at the shoreline and the point of groundwater discharge to the lake. Concentrations at these points were compared to MTCA Method B surface water criteria for the indicator constituents.

Assuming a degradation rate of 10 percent of the rate determined in the lab treatability study and source concentrations that exceed the solubility limit, all

3 ICOCs would attenuate to APOE concentrations below the MTCA Method B surface water standards. Naphthalene attenuates to target levels even under no degradation.

Table 4-3 presents the maximum APOC concentrations that attenuate to APOE concentrations below MTCA Method B surface water standards. The APOC concentrations were determined for three degradation rates that represent an active aeration system. To conservatively represent natural attenuation (no active treatment or aeration), the fate and transport modeling was also performed assuming no degradation. The maximum APOC concentrations can be used to establish target remediation levels. The product and matrix leachate concentrations are taken from the treatability study (RETEC, 1997d).

Three source concentrations are presented in this section to provide perspective on the predicted groundwater concentrations at the APOC that will attenuate below Method B surface water standards at the APOE. Table 4-3 presents these concentrations in decreasing order: solubility limit, product leachate and matrix leachate concentrations. The solubility limit is the most conservative assumed APOC concentration as it represents the maximum concentration that would occur in a solution of pure compound and water where no other competing dissolved contaminants are present. The maximum concentrations found in source areas near the shoreline are less than the product leachate value for benzene, approximately the same as the solubility limit for chrysene and approximately the same as the product leachate value for naphthalene.

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Table 4-3 Predicted Groundwater Concentrations at the APOC That Attenuate Below Method B Surface Water Standards at the APOE

Contaminant of Concern	Degradation Rate 1/day	Degradation Rate Justification	Quendall Pond Near Shore Area Shallow Nearshore Wall Maximum Permissible POC Concentration mg/L	May Creek Near Shore Area Shallow Nearshore Wall Maximum Permissible POC Concentration mg/L
benzene	0.535	Lab rate *0.1	>S	>S
benzene	0.054	Lab rate * 0.01	71.35	>S
benzene	0.043	Low Lit Value	26.06	>S
benzene	0.000	No Degredation	0.07	0.40
chrysene	0.0549	High Lit Value	>S	>S
chrysene	0.0055	Average Lit Value	0.000140	0.00160
chrysene	0.0007	Low Lit Value	0.000056	0.00032
chrysene	0.0000	No Degredation	0.000050	0.00030
naphthalene	0.516	Lab rate * 0.1	>S	>S
naphthalene	0.052	Lab rate * 0.01	>S	>S
naphthalene	0.035	Low Lit Value	>S	>S
naphthalene	0.000	No Degredation	16.15	>S

Notes:

Degradation rates:

The lab degredation rates are taken from the Port Quendall treatability study (RETEC, 1997d). The benzene and naphthalene degredation rates are taken from the column study. The Chrysene degredation rate is taken from the respirometry testing as chrysene was at an undetectable concentration in the column tests.

Lab Rate *0.1:

This is one order of magnitude lower than the degradation rate that was calculated in the Port Quendall treatability study.

Lab Rate *0.01:

This is two orders of magnitude lower than the degradation rate that was calculated in the Port Quendall treatability study.

Low/Avg/high Literature Value:

These are based on the aerobic degradation rates published in the *Handbook of Environmental Degradation Rates* (Howard, 1991).

Maximum Source Concentration:

The maximum source concentration that will not cause a violation of the MTCA Method B Surface Water Limit at the Point of Exposure
>S indicates that the permissible source concentration is greater than the solubility limit of that particular contaminant.

5 Feasibility Study Alternatives Analysis

The Port Quendall FS (RETEC, 1997c) evaluates a matrix of environmental remedial technologies. Twelve remedial alternatives comprised of these various technologies are presented in Section 6 of the FS. Four representative alternatives were modeled to predict the APOC and APOE benzene and chrysene concentrations. Naphthalene was determined to be an insignificant ICOC (Section 4) and therefore, it was not evaluated.

5.1 Alternatives Evaluated

The following four alternatives were modeled:

No Action - This alternative was not included in the FS, but is provided as a baseline for comparison purposes. The existing site conditions do not include a fill area or containment wall and both the nearshore and farshore DNAPL sources are present.

Alternative #1 - ACO/BD1 - This alternative involves constructing a 2.9 acre CDF as well as a 30 foot deep containment wall along the existing shoreline and outer edge of the fill unit.

This alternative does not include any soil treatment. The Quendall Pond and May Creek Nearshore source areas outlined in the RETEC FS are critical due to their dimensions and their proximity to the shoreline. The critical source area is defined as the source area resulting in the greatest APOC and APOE concentrations.

Alternative #7 - AC2/BD1 - This alternative assumes a 2.9 acre CDF will be constructed as well as a 30-foot deep containment wall along the existing shoreline and outer edge of the fill unit.

The Quendall Pond and May Creek Nearshore sources are removed. The critical sources then become either the residual contaminants associated with the nearshore excavations or the farshore sources associated with the old still house and the north sump. All of the potential critical sources have been evaluated.

Alternative #10 - AC3/BD1 - This alternative assumes a 2.9 acre CDF is constructed as well as a 30-foot deep containment wall along the existing shoreline and outer edge of the fill unit.

All of the DNAPL sources are removed in this alternative. The critical sources are the residual contamination associated with the nearshore source area excavations. These source areas are critical due to their dimensions and their proximity to the shoreline.

5.2 Input Parameters

5.2.1 Source Characterization

The sources were grouped according to their proximity to the shore. The nearshore sources include the Quendall Pond and May Creek sources. The farshore sources include the still house and the north sump. Figure 5-1 illustrates the source locations, areal extents, thicknesses and source below the water table.

Pre- and post-excavation concentrations were selected to represent anticipated source concentrations before and after source removal. The concentrations selected have been evaluated and justified in comparison to the existing site concentrations.

The source concentrations for the nearshore and farshore source areas are shown in Table 5-1. These concentrations are based on the treatability study (RETEC, 1997d) and site data. Where applicable, the rationale for the source concentrations reference site groundwater data presented in Figures 5-2 and 5-3.

The pre excavation concentrations represent the maximum concentration associated with the given source area. The post-excavation concentrations are selected to represent the source area concentrations anticipated after source removal as described in the FS (RETEC 1997).

The representative nearshore source area concentrations are higher than the farshore source areas to reflect the groundwater contaminant distributions presented in Figures 5-2 and 5-3.

5.2.2 Flow and Mixing Parameters

Refer to Section 4.2.2 for the flow and mixing parameters used in the fate and transport modeling.

Table 5-1 Indicator Contaminants of Concern: Rationale for Input Source Concentrations

	Nearshore DNAPL Source		Farshore DNAPL Source	
	Pre-excavation mg/L	Post-excavation mg/L	Pre-excavation mg/L	Post-excavation mg/L
Benzene	16.5	1.5	1.5	0.0005
Rationale	Product leachate concentration & max nearshore well is BH-5 @ 3.3 mg/L	Matrix leachate concentration & max nearshore well outside of excavation footprint is BH-18A @ 1.7 mg/L	Matrix leachate concentration - several orders of magnitude greater than reported concentrations in farshore area	Half of the detection limit of benzene reported for wells BH-22 and BH-27
Chrysene	0.006	0.0005	0.006	0.0005
Rationale	Solubility limit of chrysene and max nearshore well is BH-12 @ 0.004 mg/L	Half of the detection limit of chrysene as reported by ARI	Solubility limit of chrysene and max farshore well is BH-23 @ 0.0041 mg/L	Half of the detection limit of chrysene as reported by ARI

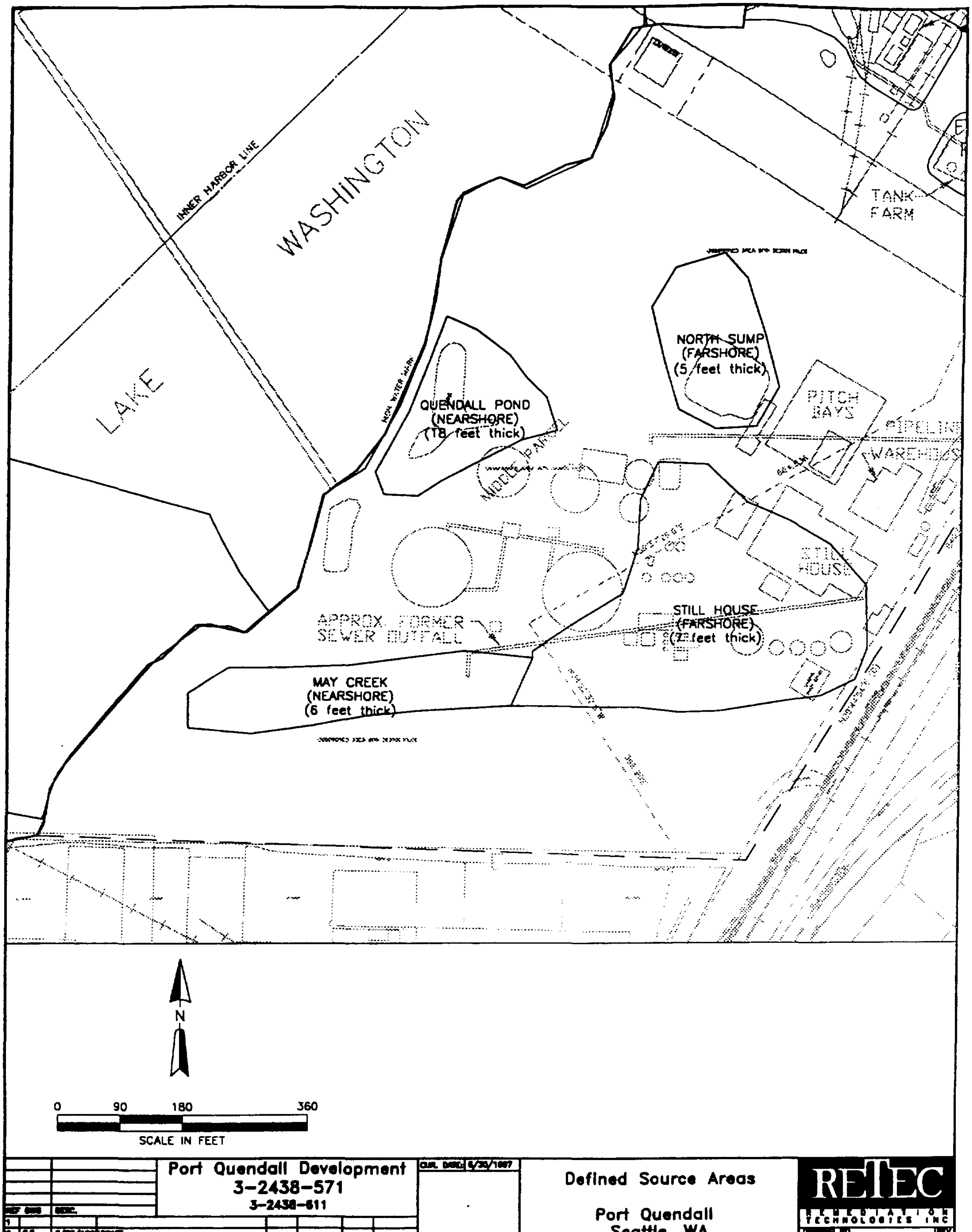
5.2.3 First-Order Decay Parameters

The first order decay rate is used to represent contaminant degradation associated with biosparging.

Benzene degradation due to biosparging was simulated by a rate of 1/10 of the aerobic decay rate determined in the column study (RETEC, 1997d). Chrysene degradation due to biosparging was simulated by a rate of 1/10 of the aerobic decay rate of pyrene determined in the column study (RETEC, 1997d). The kinetics of pyrene have been substituted due to the inability to study chrysene degradation given its high detection limit. The substitution is justified when considering the similar kinetics quoted in the literature, and the similar molecular structure of chrysene and pyrene. The half lives and degradation rates of benzene, chrysene and pyrene are presented in Appendix A5.

5.2.4 Retardation Factors

Refer to section 4.2.4 for the retardation factors used in the model.



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Defined Source Areas

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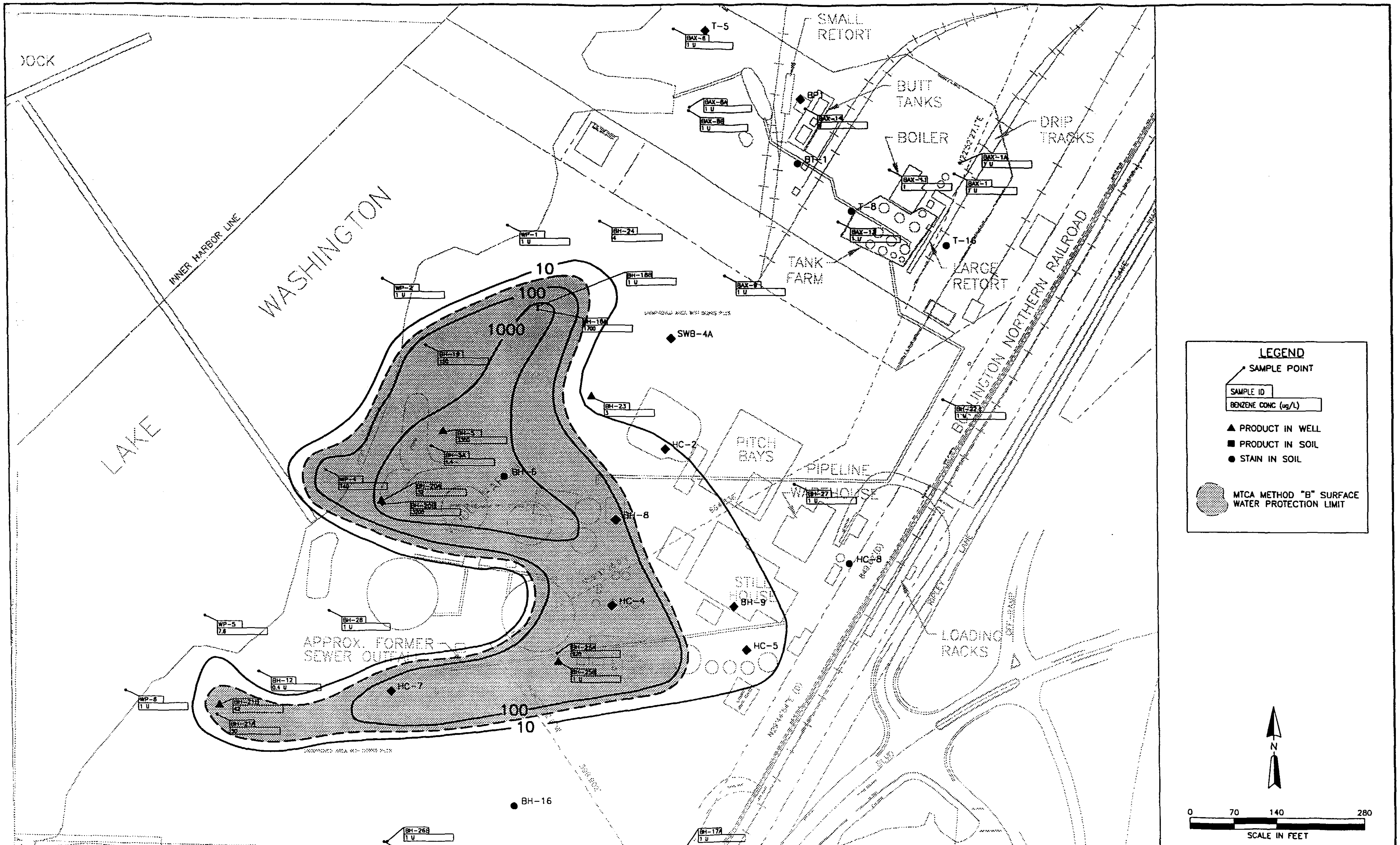

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BENZENE
SHALLOW GROUNDWATER
CONCENTRATIONS

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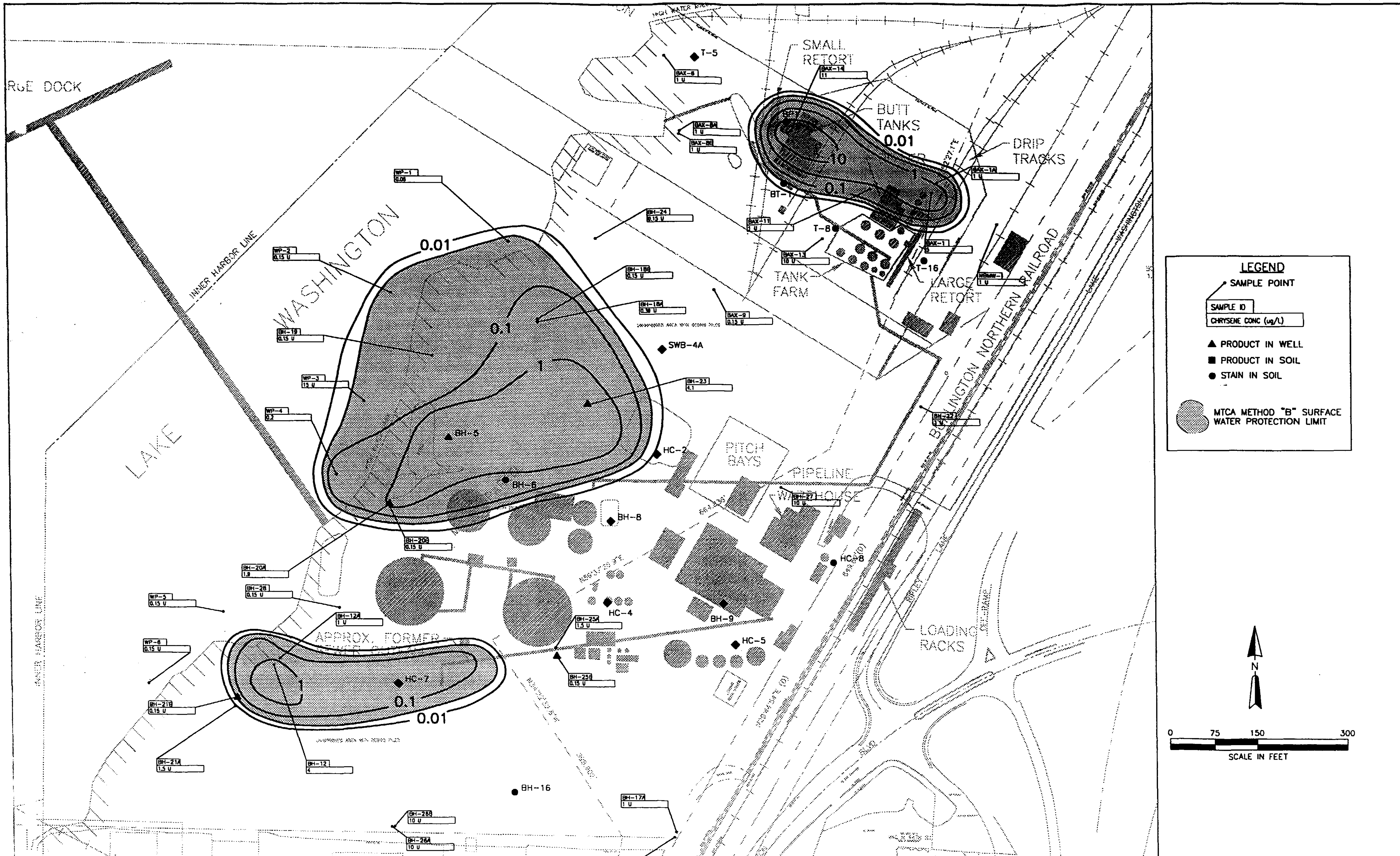

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CHRYSENE
SHALLOW GROUNDWATER
CONCENTRATIONS

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5.2.5 Distance from Source to APOC and APOE

Using the input parameters specified above, the model estimated the APOC and APOE concentrations. The distance from the source areas to the APOC and APOE were determined as part of the particle tracking analysis performed using the MODPATH module of MODFLOW. The particle tracking results are provided in Appendix A5.

5.3 Results of the Feasibility Study Alternatives Analysis

The alternatives analysis fate and transport modeling is presented in Appendix A8 and discussed below.

No Action

If no remedial action is taken, the model predicts APOC and APOE concentrations that exceed the MTCA Method B Surface Water Criteria for both benzene and chrysene. The model predicts that the critical source is the Quendall Pond nearshore source. This prediction is reasonable given the dimensions of the source and its proximity to the shoreline.

Alternative #1 - ACO/BD1

The model predicts that Alternative #1 will meet MTCA Method B Surface Water Criteria for benzene and chrysene concentrations at the APOE and the APOC if a 50 foot biosparging zone is modeled upgradient of the APOC. The MTCA standard is not achieved at the APOC when the biosparging zone is located downgradient.

The 2.9 acre CDF fill results in a greater path length from the Quendall Pond source to the APOC. For this reason, the model predicts May Creek as the critical source despite its smaller dimensions. The CDF alignment could be altered to provide a buffer zone for both the Quendall Pond source and the May Creek source, rather than just the Quendall Pond source.

Alternative #7 - AC2/BD1

The model predicts that Alternative #7 will meet MTCA Method B Surface Water Criteria for benzene and chrysene concentrations at the APOE but not the APOC. The model predicts that the nearshore and farshore sources contribute roughly equally (same order of magnitude) to the APOC concentrations. The model could be interpreted as over predicting the impact of the farshore sources when evaluating the existing contaminant distribution.

A sparging zone location upgradient of the APOC was not evaluated for this alternative. The sparging zone of 50 ft, as modeled for Alternative #1, would be more than adequate to result in an APOC concentration below MTCA Method B Surface Water Criteria. This is apparent when considering the lower APOC concentrations predicted as a result of source removal.

Alternative #10 - AC3/BD1

The model predicts that Alternative #10 will meet MTCA Method B Surface Water Criteria for benzene and chrysene concentrations at the APOE but not the APOC. The critical source for this alternative is the residual concentration at May Creek.

A sparging zone location upgradient of the APOC was not evaluated for this alternative. The sparging zone of 50 ft, as modeled for Alternative #1, would be more than adequate to result in a APOC concentration below MTCA Method B Surface Water Criteria. This is apparent when considering the lower APOC concentrations predicted as a result of source removal.

5.4 Discussion

The model predictions presented in this section emphasize the value of biosparging as a remedial alternative.

The attenuation lengths of the various plumes modeled in this section could be evaluated to determine the necessary dimensions of a biosparging system. The attenuation length of a plume is defined as the distance from the source to the downgradient centerline point where the concentration is below a given criteria. The maximum attenuation length is associated with chrysene originating at the nearshore sources at pre-excavation concentrations. The longest attenuation length is 45 ft. A biosparging zone 50 ft in length located upgradient of the APOC resulted in attenuation of benzene and chrysene to below surface water criteria at the APOC. Nearshore source removal reduces this plume attenuation length to 26 ft and therefore an even smaller biosparging zone would be necessary. Refer to Figure 5-4 for a schematic of an extended biosparging zone. It should be noted that this assumes there is no free product within the biosparging zone. Table 5-2 lists the APOC and APOE benzene and chrysene concentrations associated with the Quendall Pond source area that are predicted for the various alternatives.

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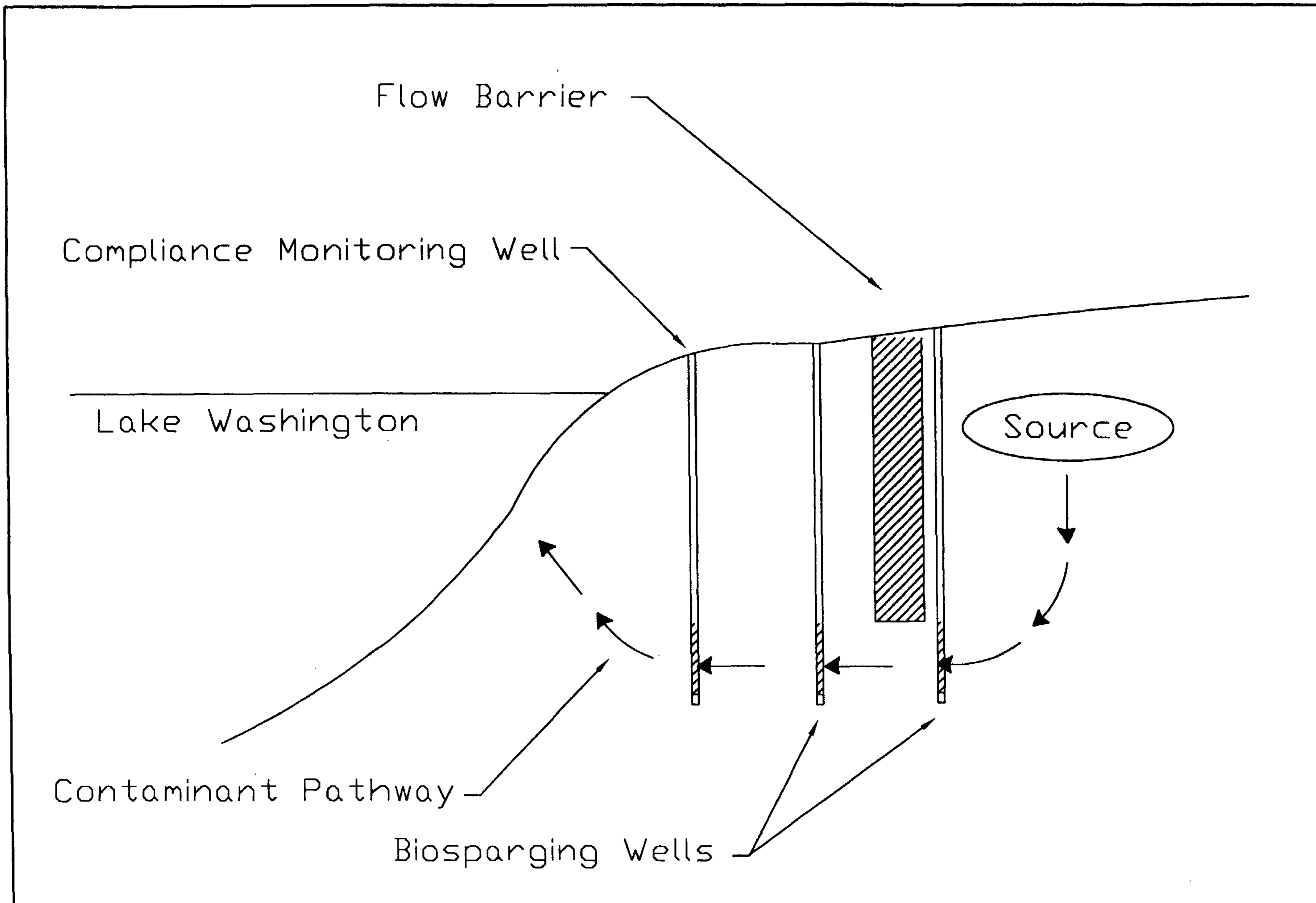
Table 5-2 Concentrations of Benzene and Chrysene at the APOC and APOE for the Various Alternatives

Alternative	Fill	Wall	Source Removal	Location of Biosparging System	Benzene POC Concentration (mg/L)	Benzene POE Concentration (mg/L)	Chrysene POC Concentration (mg/L)	Chrysene POE Concentration (mg/L)
No Action	None	none	none	Not Applicable	1.53E+01	6.90E+00	5.57E-03	2.51E-03
Alternative #1 ACO/BD1	2.9 Acre CDF	30 foot wall	none	At APOC	3.54E+00	2.96E-19	1.29E-03	7.04E-09
Alternative #1 ACO/BD1	2.9 Acre CDF	30 foot wall	none	50 Feet Upgradient of APOC	1.78E-08	1.49E-27	2.47E-05	1.35E-10
Alternative #7 AC2/BD1	2.9 Acre CDF	30 foot wall	Nearshore DNAPL	At APOC	3.22E-01	2.69E-20	1.07E-04	5.84E-10
Alternative #10 AC3/BD1	2.9 Acre CDF	30 foot wall	All DNAPL	At APOC	3.22E-01	2.69E-20	1.07E-04	5.84E-10

Notes:
The APOC and APOE concentrations are presented for the Quendall Pond Source.
Refer to table 5-1 for the nearshore and farshore pre and post excavation concentrations.

FATE2 was used to model the contaminant transport from the source areas to the APOC and then from the APOC to the APOE. No degradation was assumed from the source areas to the APOC. Biosparging was represented with a degradation rate equal to 1/10 of the aerobic degradation rate determined in the Lab Treatability Study [RETEC 1997]., applied from the APOC to the APOE. No degradation was assumed from the APOC to the APOE for the no action scenario (no biosparging).
The MTCA Method B Surface Water Limit for benzene is 4.3 x10-2 mg/L.
The MTCA Method B Surface Water Limit for chrysene is 2.96 x10-5 mg/L
The Feasibility Study Alternatives are cross referenced to the alternatives presented in the Feasibility Study (RETEC, 1997) (e.g., AC0/BD1).



REF DWG DESC.
0
0 SBC 7-9-97
NO DRWN DATE REVISION CHKD DATE APPVD DATE

Port Quendall Development
3-2438-571

SCALE NONE
CAD FILE biosparg

Expanded Biosparging Zone Schematic

Port Quendall
Seattle, WA

RETEC
REMEDIATION TECHNOLOGIES INC
DRAWING NO. Figure 5-4 REV 0

6 Discussion

6.1 Containment Wall Horizontal Alignments

The preferred barrier wall alignment depends on the fate of the Quendall Pond Nearshore source area. If the source area remains untreated, the outer wall alignment significantly increases the travel time to the APOE, making the nearshore CDF alignment the preferred alternative. However, if the Quendall Pond Nearshore source area is treated, the increased particle travel time associated with the nearshore wall alignments becomes insignificant.

The relative remedial value of the three wall alignments was evaluated by studying the particle tracking travel times of a conservative tracer from the four source areas to the APOE and by comparing the pumping rates required for capture of the contaminated groundwater plume.

The northern and southern portions of the wall alignment are identical for all three scenarios. The travel times of particles originating in sources that are directly upgradient of these portions of the wall do not change significantly when the containment wall alignments are altered. However, the travel times of particles originating in sources that are directly upgradient of the center portion of the wall (i.e., Quendall Pond) do increase significantly as the wall alignment moves out into the lake.

Given the natural flow patterns that occur on the site (downward in the upland portion of the site, relatively horizontal through the sand unit, and upward into the lake), it is not surprising that the flow barriers do not provide a consistently significant extended travel time to the APOE. The flow barriers force a flow pattern that mimics the naturally occurring tendency and, in fact, shortens the travel times of particles originating in the farshore source areas due to the tendency to flow more directly down and out of the silty fill unit into the more conductive sand unit.

The installation of a barrier wall reduces the cumulative pumping rate required to capture the contaminated groundwater plume by approximately 80 percent. However, the pumping rate required for capture is not sensitive to the horizontal alignment of the barrier wall.

6.2 Containment Wall Depths

Increasing the barrier wall depth into the sand aquifer significantly reduces the pumping rate required for capture of the contaminated groundwater plume. For all three alignments evaluated, the deeper wall results in significantly lower pumping rates required for capture. Increased wall depths however, have a limited effect on the travel times of impacted groundwater as it flows to the APOE. Given that groundwater extraction is a backup technology, the additional cost of construction of the deeper wall is not justified by its remedial benefit.

The relative remedial value of the two wall depths can be evaluated by studying the particle tracking travel times of a conservative tracer from the four source areas to the APOE and by comparing the pumping rates required for capture of the contaminated groundwater plume. The increased travel time associated with the deeper wall alignment is insignificant for most of the particles except those that originate in the May Creek Nearshore and the Quendall Pond source areas.

Particles that originate in the May Creek and Quendall Pond source areas have a relatively short path to the APOE compared to the base case scenario. The proposed flow barrier is immediately downgradient of these source areas. A deeper wall would increase travel times for particles from these areas by causing them to travel below the wall before moving up and out to the APOE. However, the increased travel time is limited due to the flow pattern and the high conductivity of the sand, and does not justify the additional expense of a deeper wall.

The pumping rates that are required for contaminated groundwater capture can be evaluated and compared to the rate required for capture of the base case scenario. The shallow barrier wall requires a pumping rate equal to 27 percent of the base case scenario. The deeper barrier wall requires a pumping rate equal to 15 percent of the base case scenario. It is anticipated that the deeper wall inhibits flow from the conductive sand unit below Lake Washington, thereby requiring a lower pumping rate.

6.3 Pumping Rates

RETEC calculated the pumping rates required for the capture of the contaminated groundwater plume and the dewatering of several source removal areas.

By applying a safety factor of 2 (doubling the predicted rates in order to be conservative), RETEC estimates that capture of the contaminated groundwater plume will require cumulative pumping rates of 290 gpm for the base case scenario, 88 gpm for the shallow walls and 52 gpm for the deeper walls. The cumulative pumping rates are not significantly affected by the barrier wall alignment.

The FS (RETEC, 1997c) assumes a treatment cost of $10 per 1,000 gallons of contaminated water. This does not reflect the costs associated with dewatering system installation.

6.4 Dewatering Source Areas

The model predicts that pumping rates of 10 to 32 gpm will be required for the dewatering of the various source areas assuming that the nearshore source areas will be excavated using flow barriers.

RETEC's FS assumes a treatment cost of $10 per 1,000 gallons of contaminated water. This does not reflect the costs associated with dewatering system installation.

6.5 Natural Attenuation

Natural attenuation was modeled assuming no biodegradation. The infeasibility of natural attenuation is apparent when comparing the predicted groundwater concentrations at the APOC to the anticipated groundwater concentrations associated with existing source areas.

6.6 Aeration

Aeration is a feasible option for groundwater remediation. This was demonstrated with fate and transport modeling using degradation rates conservatively based on the lab treatability study and literature values. Aeration at the shoreline consistently produced APOE concentrations below Method B surface water criteria. Aeration could also treat groundwater to target levels at a shoreline point of compliance given a sufficiently large biosparging zone and no free product within a 45-foot zone.

6.7 Source Removal

Source removal actions are not necessary to achieve target levels at a point of exposure. Source removal actions can improve the effectiveness of a biosparging system. Source removal actions may improve groundwater quality by an order of magnitude at an assumed shoreline point of compliance over no source removal. Nearshore DNAPL areas have more of an impact on groundwater quality than the farshore areas.

7 References

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APPENDIX A

Appendix A1 Hydraulic Conductivity Calculations

To represent the three-foot thick containment walls within the thirty-foot cells of the groundwater model, an average hydraulic conductivity was calculated. Flow perpendicular to layering is dominated by layers of low conductivity (containment wall) and this is reflected by use of a harmonic mean for the calculations.

Appendix A2 Particle Tracking Output - Groundwater Capture Analysis

Particle tracking was performed using the MODPATH routine of MODFLOW. MODPATH predicts the 3-dimensional, time-dependent trajectory of particles of conservative non-reactive tracers that originate in specified source locations. Particles were placed around the perimeter of an assumed dissolved groundwater plume footprint. Eight recovery wells were simulated along the upgradient edge of the containment wall and the pumping rates of the wells were adjusted such that all of the particles were captured in the wells.

The pumping rates required for contaminated groundwater capture are presented in tabular form.

VISUAL MODLFOW output illustrates the groundwater capture flow patterns, acpture zones and individual well pumping rates required for capture.

Appendix A3 Particle Tracking - Source Areas

Particle tracking was performed using the MODPATH subroutine of MODFLOW. MODPATH predicts the 3-dimensional, time-dependent trajectory of a particle of a conservative non reactive tracer that originates in a specified source area. The source areas are shown on a site. The horizontal and vertical projections of the three dimensional pathline of the tracer are shown in the particle tracking output presented in this appendix.

Six source areas are presented to represent the major source areas as defined by the Feasibility Study [RETEC 1997].

The chevrons that are observed along the projected pathlines indicate 200 days of travel time.

Particle tracking results are summarized in a tabular format that includes travel times from the source areas to the assumed point of compliance (shoreline) and assumed point of exposure (Lake Washington).

Appendix A7 Dewatering Analysis

The dewatering rates required for source removal are presented in this appendix along with a sensitivity analysis of the dewatering rate to the horizontal conductivity.

The sensitivity analysis determines the sensitivity of the model's dewatering predictions to the input conductivity.

Appendix A8 Feasibility Study Alternatives Modeling Output

The fate and transport modeling presented in Section 5 of this report is based on the model output included in this appendix. The modeling is intended to evaluate a specific set of alternatives that are proposed in the Feasibility Study [RETEC 1997c]. This modeling is also supported by Appendix A5, FATE2 Input Parameters.

The two part modeling presented here evaluates the fate of the ICOC's as they travel from the source areas to the APOC and then from the APOC to the APOE. The degradation rates for the two legs of this analysis can be assigned individually to represent degradation associated with biosparging that is modeled downgradient of the APOC.

The specific source characterization is presented here and includes the source dimensions and pathlengths from the source to the APOC and from the APOC to the APOE.

Appendix A9 Preliminary Groundwater Memo, Ecology Comments and Responses

The preliminary groundwater memo, Ecologies comments, and RETECs response are included in this appendix. These documents compreise the scope of work for the Port Quendall modeling effort.

Appendix A10 Model Calibration Documentation

Figures and tables associated with the groundwater model calibration are presented here. The model was calibrated to three sets of water levels; average water levels, August 1995 and January 1996. The calibration statistics for these three calibration sets are provided. The statistics are an indication of the ability of the model to predict the observed conditions.

Appendix A1

Wall Conductivity Calculations

Conductivity with Wall

Determine hydraulic conductivity, K through the wall.

K parallel to layering is dominated by low K (even thin) layers.

Use weighted harmonic mean*

$$K = \frac{\textit{thickness cell}}{\sum \frac{\textit{thickness layer}}{\textit{cond. layer}}}$$

$$K = \frac{30'}{\left(\frac{27}{3}\right) + \left(\frac{3}{2.8 \times 10^{-4}}\right)} = 2.798 \times 10^{-3}$$

Assumes that the wall is 3 feet thick with K_{wall}l = 2.8 x 10^{-4} ft/day.

When the wall is in the sand unit

K sand = 40 ft/day

$$K_{cell} = \frac{30'}{\left(\frac{27}{40}\right) + \left(\frac{3}{2.8 \times 10^{-4}}\right)} = 2.799 \times 10^{-3}$$

* Refer to "Earth 458-Physical Hydrogeology", CW Masse, RV Nicholson Waterloo Centre for Groundwater Research, Dept. of Earth Sciences University of Waterloo, May 1991.

Appendix A2

Particle Tracking Output - Capture Analysis

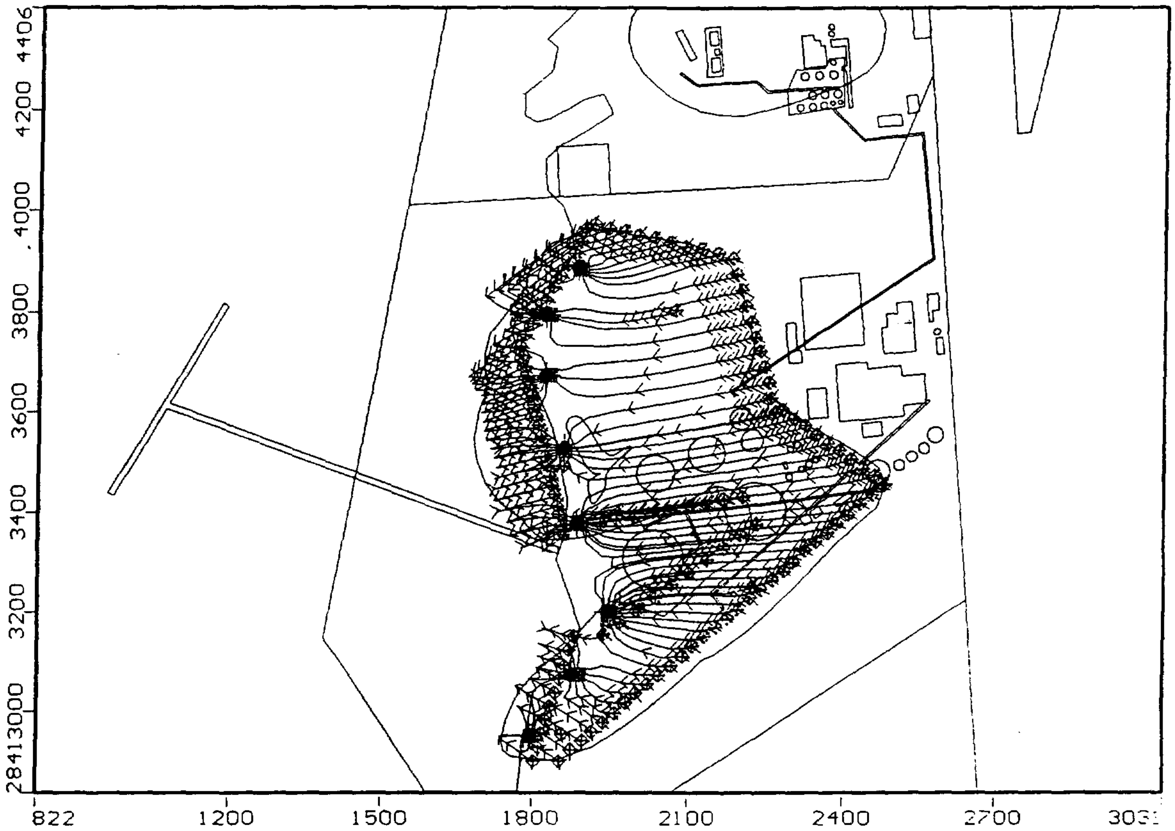
Port Quendall Groundwater Analysis
Capture Analysis

Simulation	Run	Total Pumping Rate ft^3/day	Gpm	% of base case	Number of Wells	Screened Unit	Alignment	Notes
Base Case	**24**	**28000**	**145.6**	**NA**	**8**	**sand**	**along shore**	Taken as base case for the comparative analysis (% of base case pumping rate)
Upland wall to 30'	19	8500	44.2	30%	6	sand	along shore	pumping just upgradient of the wall capitalizes on the flow convergence
Upland Wall to 50'	20	5000	26	18%	8	sand	along shore	pumping just upgradient of the wall capitalizes on the flow convergence
Nearshore Wall to 30'	21	7250	37.7	26%	8	sand	along shore/Fill	pumping just upgradient of the wall capitalizes on the flow convergence
Nearshore Wall to 50'	22	4500	23.4	16%	8	sand	along shore/Fill	pumping just upgradient of the wall capitalizes on the flow convergence
Nearshore CDF Walll to 30'	28	6750	35.1	24%	8	sand	along shore/Fill	pumping just upgradient of the wall capitalizes on the flow convergence
Nearshore CDF Walll to 50'	29	3750	19.5	13%	8	sand	along shore/Fill	pumping just upgradient of the wall capitalizes on the flow convergence

Notes:
The capture analysis was performed by overlaying dissolved plume extents for five constituents (benzene, chrysene, naphthalane, benzoapyrene and pentachlorophenol) exceeding MTCA method B surface water criteria. Particles were placed around the perimeter of this area at the a depth corresponding to the center of the silty/fill unit. Wells were installed in the model and the appropriate pumping rates were determined by adjusting the rates up and down to efficiently capture all of the particles.

The downgradient edge of the dissolved MTCA method B overlay is downgradient of the shoreline in some areas. Due to the inability to practically install wells further downgradient that the existing shoreline, the particle tracking analysis did not consider the capture of these particles. For instances where the dissolved plume overlay was west of the shoreline, the downdgradient limit for placement of particles was either the shoreline, or slightly upgradient (east) of the groundwater barrier.

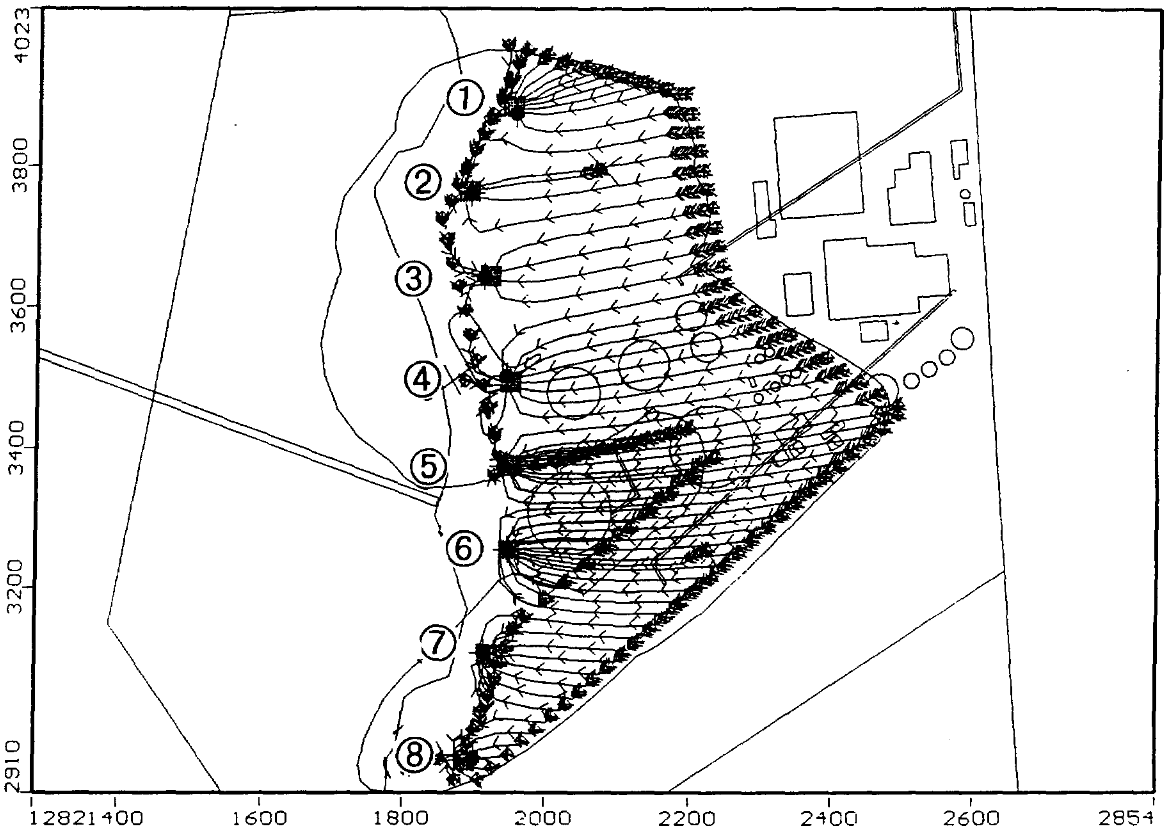
The well screens were typically placed at a depth below the silt/fill and sand unit interface (with the exception of run 23 in which the wells were placed in the silt/fill unit.) This typical depth places the screen center at the bottom of the 30' bgs wall, and above the bottom of the 50' bgs wall. For the 50' bgs wall, the wells screens could either be placed above or below the wall however, preliminary testing confirmed that it is more efficient to place the well screens above the bottom of the wall (the zone of influence is reflected and therefore stretched upgradient and less lake water is drawn into the wells).



8 wells @ 3500 ft³/day (18.2 gpm)

Total 145.6 gpm

Retec Inc. – Seattle, WA Project: Port Quendall Company Description: Base Case – wells in sand Modeller: SBC 3 Jun 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Layer: 2

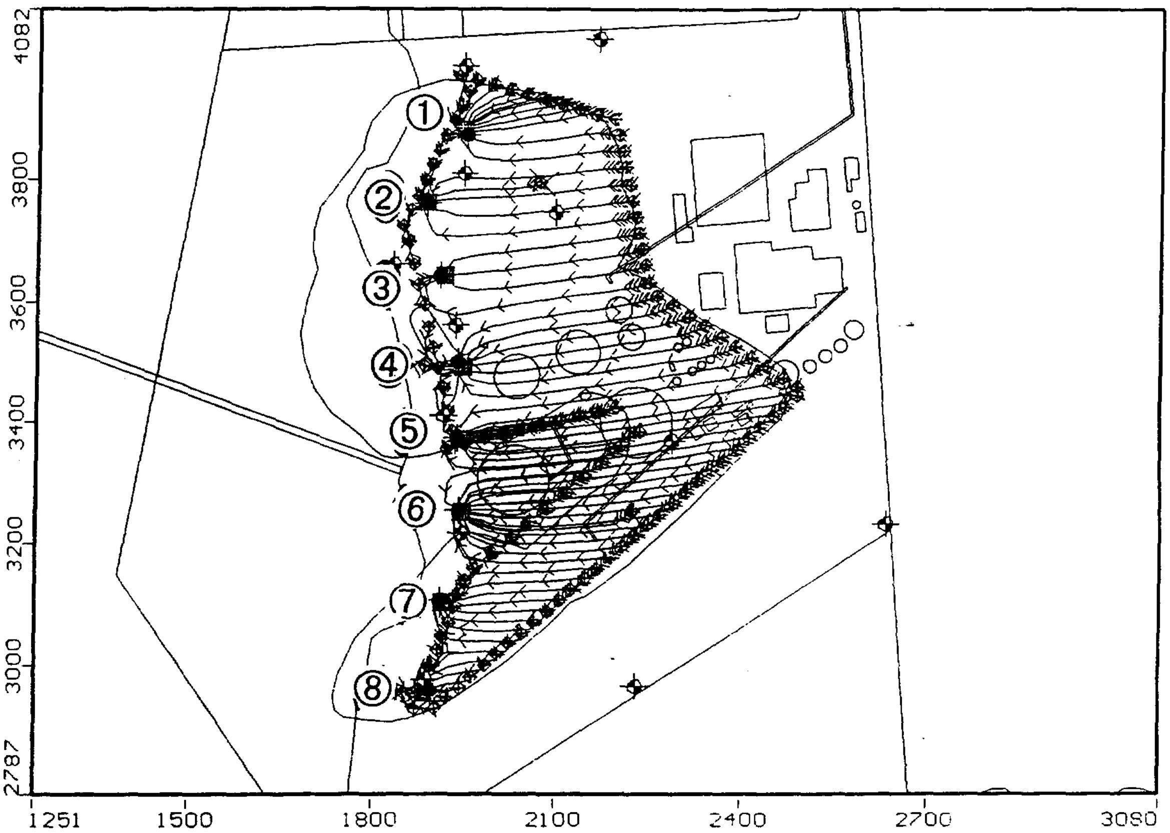


Wells ①, ②, ③ @ 1000 ft³/day
Wells ④, ⑥ @ 1250 ft³/day
Wells ⑤, ⑦, ⑧ @ 1000 ft³/day

Total 8500 ft³/day or 44.2 GPM

Retec Inc. – Seattle, WA Project: Port Quendall Company Description: Wall – K=2.8e–3 to btm L3 Modeller: SBC 28 May 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Layer: 2

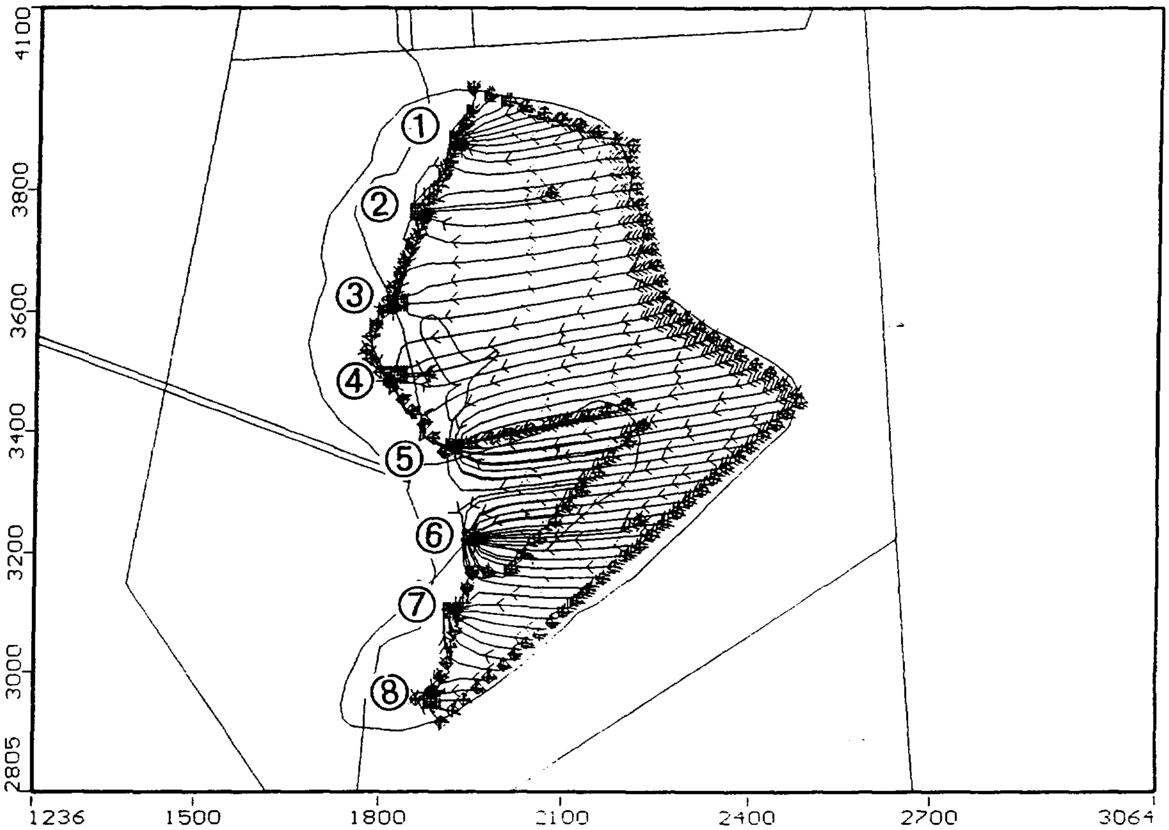
RUN 20



①, ②, ④, ⑥ @ 750 ft³/day
③, ⑤, ⑦, ⑧ @ 500 ft³/day

Total 5000 ft³/day or 26.6 GPM

Retec Inc. – Seattle, WA Project: Port Quendall Company Description: Wall – K=2.8e–3 to btm L5 Modeller: SBC 28 May 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Layer: 2



①, ⑦ @ 750 ft^3/day

②, ③, ④, ⑥ @ 1000 ft^3/day

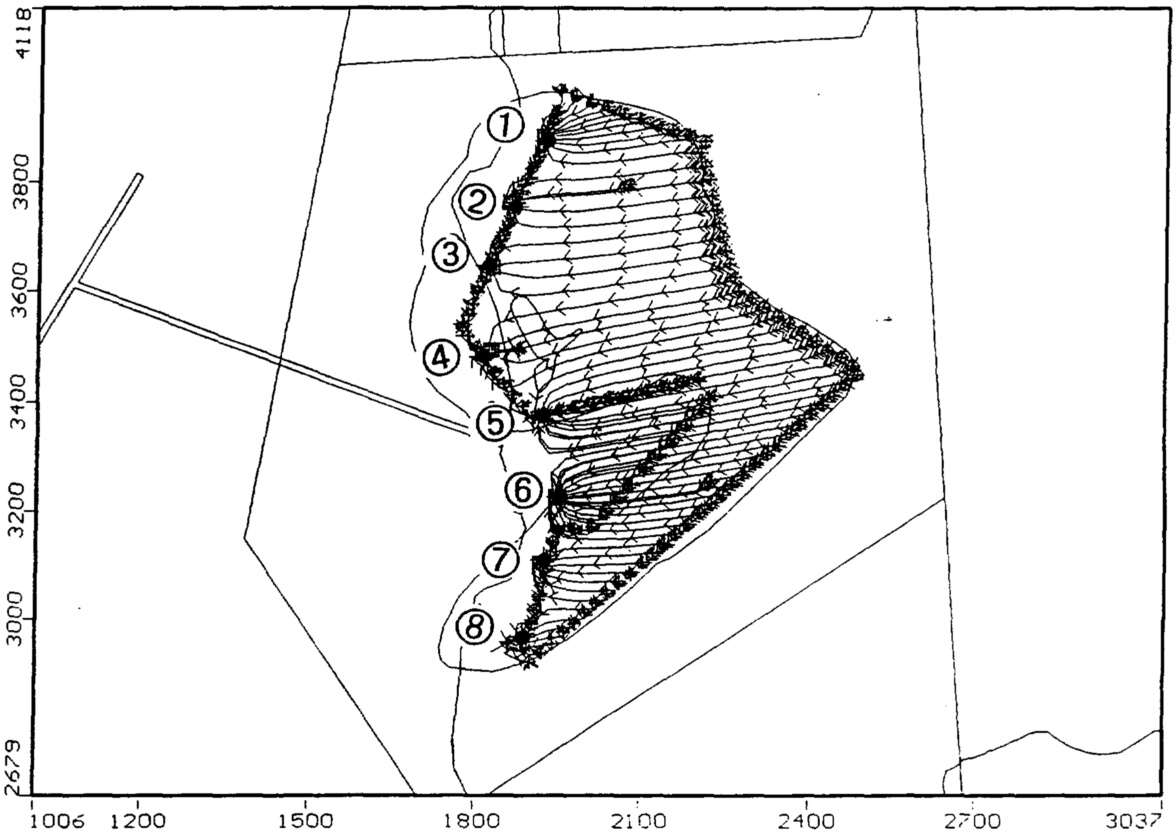
⑤ @ 1250 ft^3/day

⑧ @ 500 ft^3/day

Total 7250 ft^3/day or 37.7 GPM

Retec Inc. – Seattle, WA Project: Port Quendall Company Description: Wall to 30' Modeller: SBC 29 May 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Layer: 2

RUN 22

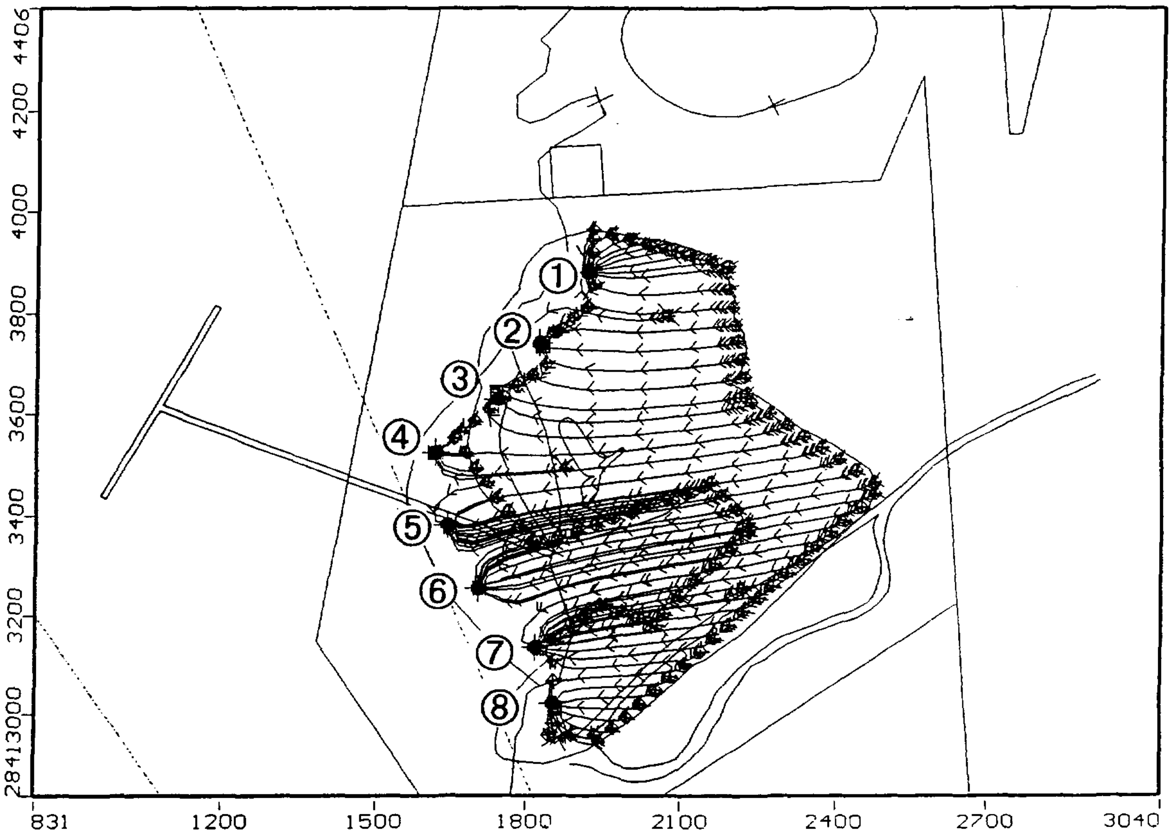


①,②, ③, ④, ⑦,⑧ @ 500 ft³/day
⑤, ⑥ @ 750 ft³/day

Total 4500 ft³/day or 23.4 GPM

Retec Inc. – Seattle, WA Project: Port Quendall Company Description: Wall to 50' bgs Modeller: SBC 29 May 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Layer: 2

RUN 28



①⑥⑦ @ **1000 ft^3/day (5.2 GPM)**

②③④⑤⑧ @ **750 ft^3/day (3.9 GPM)**

Total 6750 ft^3/day or 35.1 GPM

Retec Inc. – Seattle, WA Project: Port Quendall Company Description: Outer Fill(2.9 Ac)30'Wall Modeller: MR / SBC 2 Jun 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Layer: 2

RUN 29

①, ④, ⑤ @ 500 ft³/day (2.6 gpm)
②, ③, ⑧ @ 250 ft³/day (1.3 gpm)
⑥, ⑦ @ 750 ft³/day (3.9 gpm)

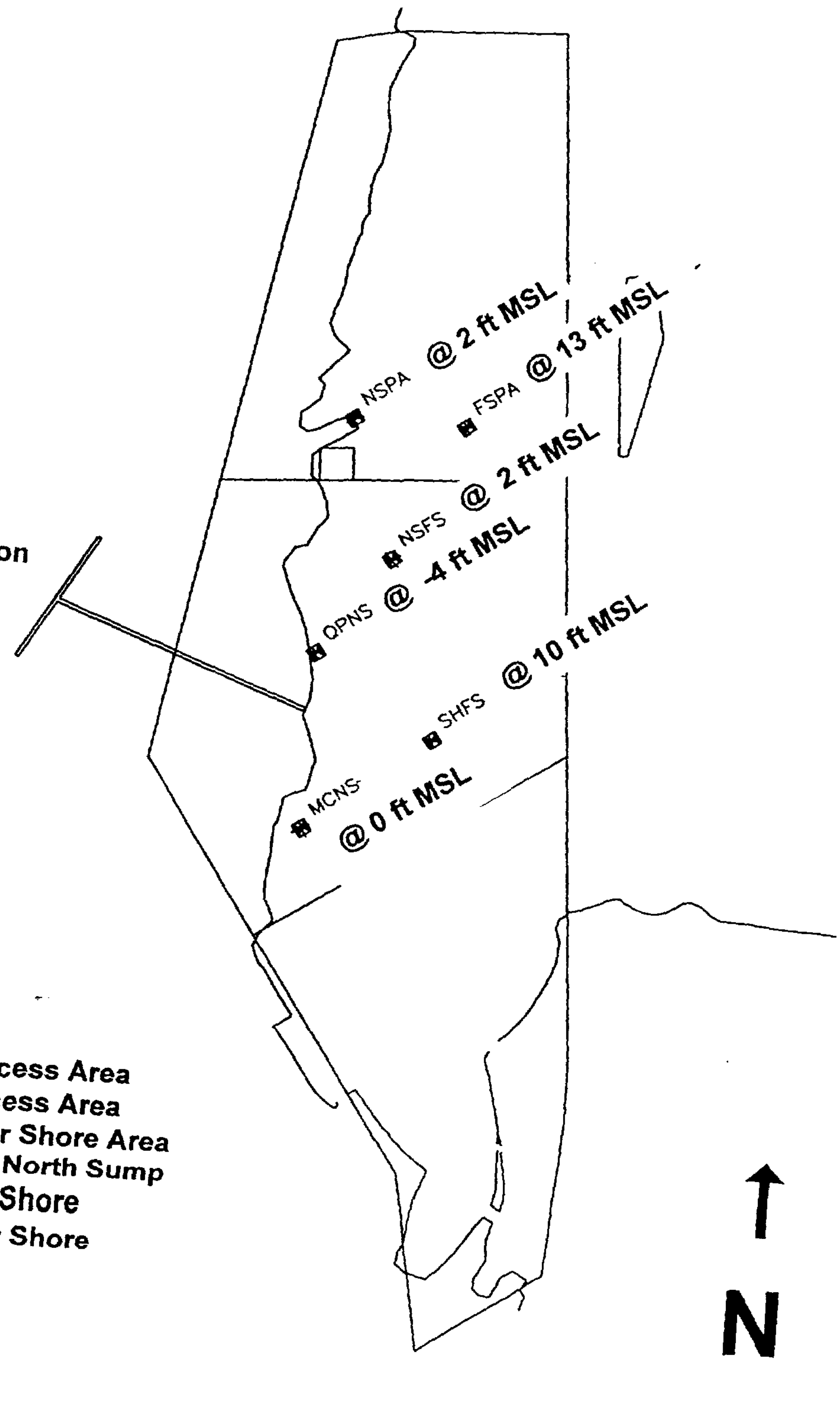
Total 3750 ft³/day or 19.5 gpm

Retec Inc. – Seattle, WA Project: Port Quendall Company Description: Outer Fill(2.9 Ac)50'Wall Modeller: MR / SBC 2 Jun 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Layer: 2

Appendix A3

Particle Tracking Output - Source Areas

Particle Tracking Source Locations



NSPA	Nearshore Process Area
FSPA	Far Shore Process Area
NSFS	North Sump Far Shore Area
QPNS	Quendall Pond North Sump
SHFS	Still House Far Shore
MCNS	May Creek Near Shore

Port Quendall Company
Particle Tracking Analysis

RUN	DESCRIPTION	PARTICLE TRACKING - Days												Comments
		NSPA -2 ft MSL		FSPA 13 ft MSL		NSFS 2 ft MSL		QPNS -4 ft MSL		SHFS 10 ft MSL		MCNS 0 ft MSL		
		Pt of Comp	Pt of Exp	Pt of Comp	Pt of Exp	Pt of Comp	Pt of Exp	Pt of Comp	Pt of Exp	Pt of Comp	Pt of Exp	Pt of Comp	Pt of Exp	
7	**Base Case**	0	800	2040	3600	2120	2740	140	600	1740	2400	280	600	
6	Upland Wall to 30 ft	0	900	2340	3460	1600	2400	200	1280	1740	2440	600	1200	
40	Upland Wall to 50 ft	0	900	2300	3500	1780	2900	700	2040	1960	3000	600	1800	
8/9	Upland Wall to 30 /50 ft - Gates	0	880	2340	3460	1800	2840	560	1960	1940	2940	800	1620	
10	Nearshore wall to 30 ft	0	880	2340	3460	1600	2420	540	1300	1760	2480	600	1160	
11	Nearshore wall to 50 ft	0	880	2340	3460	1800	2820	920	1680	1940	2940	760	1580	
12	Nearshore wall to 30/50 ft - Gates	0	880	2340	3460	1800	2820	920	1680	1940	2940	700	1480	
25	Outer Wall to 30'		880	2320	3480	1680	2440	1120	1640	2160	3000	530	1080	
27	Outer Wall to 50'		880	2320	3480	1880	2800	1240	2200	2240	3040	900	1720	

RUN	DESCRIPTION	PARTICLE TRACKING - % of base case travel time												Comments
		NSPA -2 ft MSL		FSPA 13 ft MSL		NSFS 2 ft MSL		QPNS -4 ft MSL		SHFS 10 ft MSL		MCNS 0 ft MSL		
		Pt of Comp	Pt of Exp	Pt of Comp	Pt of Exp	Pt of Comp	Pt of Exp	Pt of Comp	Pt of Exp	Pt of Comp	Pt of Exp	Pt of Comp	Pt of Exp	
7	**Base Case**	0	800	2040	3600	2120	2740	140	600	1740	2400	280	600	
6	Upland Wall to 30 ft	NA	113%	115%	96%	75%	88%	143%	213%	100%	102%	214%	200%	
40	Upland Wall to 50 ft	NA	113%	113%	97%	84%	106%	500%	340%	113%	125%	214%	300%	
8/9	Upland Wall to 30 /50 ft - Gates	NA	110%	115%	96%	85%	104%	400%	327%	111%	123%	286%	270%	
10	Nearshore wall to 30 ft	NA	110%	115%	96%	75%	88%	386%	217%	101%	103%	214%	193%	
11	Nearshore wall to 50 ft	NA	110%	115%	96%	85%	103%	657%	280%	111%	123%	271%	263%	
12	Nearshore wall to 30/50 ft - Gates	NA	110%	115%	96%	85%	103%	657%	280%	111%	123%	250%	247%	
	Outer Wall to 30'	NA	110%	114%	97%	79%	89%	800%	273%	124%	125%	189%	180%	
	Outer Wall to 50'	NA	110%	114%	97%	89%	102%	886%	367%	129%	127%	321%	287%	

Particle **Please note: The chevrons of the Visual Modlflow Output represent 200 days travel time.**

Port Quendall Groundwater Analysis
Impacted Flow Convergence Zone Analysis

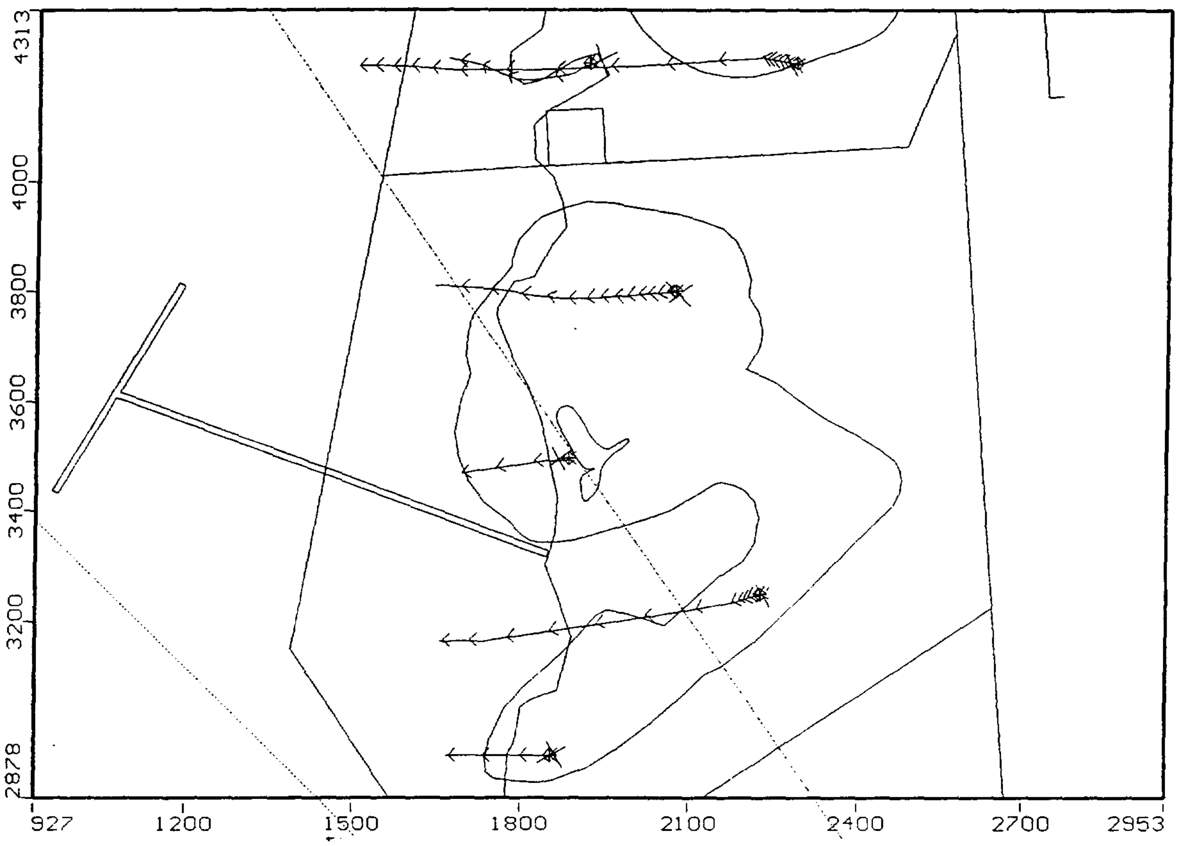
	Impacted flow convergence zone				
	Height at North Wall	Height at Center	Height at South Wall	Days in 30' cell at row	Approximated velocity
Base Case	15.8	22	11	142 or 70	.21 to .43 ft/day
Upland wall to 30'	11	15	7.5	50	0.60
Upland Wall to 50'	12.5	18.5	13.5	50	0.60
Nearshore Wall to 30'	10	20	9.5	45	0.67
Nearshore Wall to 50'	11	20	18	110	0.27
Outer Wall to 30'	10	24	8.5	60	0.50
Outer Wall to 50'	8	28	10.5	55	0.55

Notes:

The flow convergence zone is taken as the top and bottom of the zone in which particles from the east and west sides of the site are closest together. This occurs directly under the walls in all of these scenarios, presenting an opportunity for treatment of the contaminants. For the base case the zone of convergence observed in the vicinity of the shoreline.

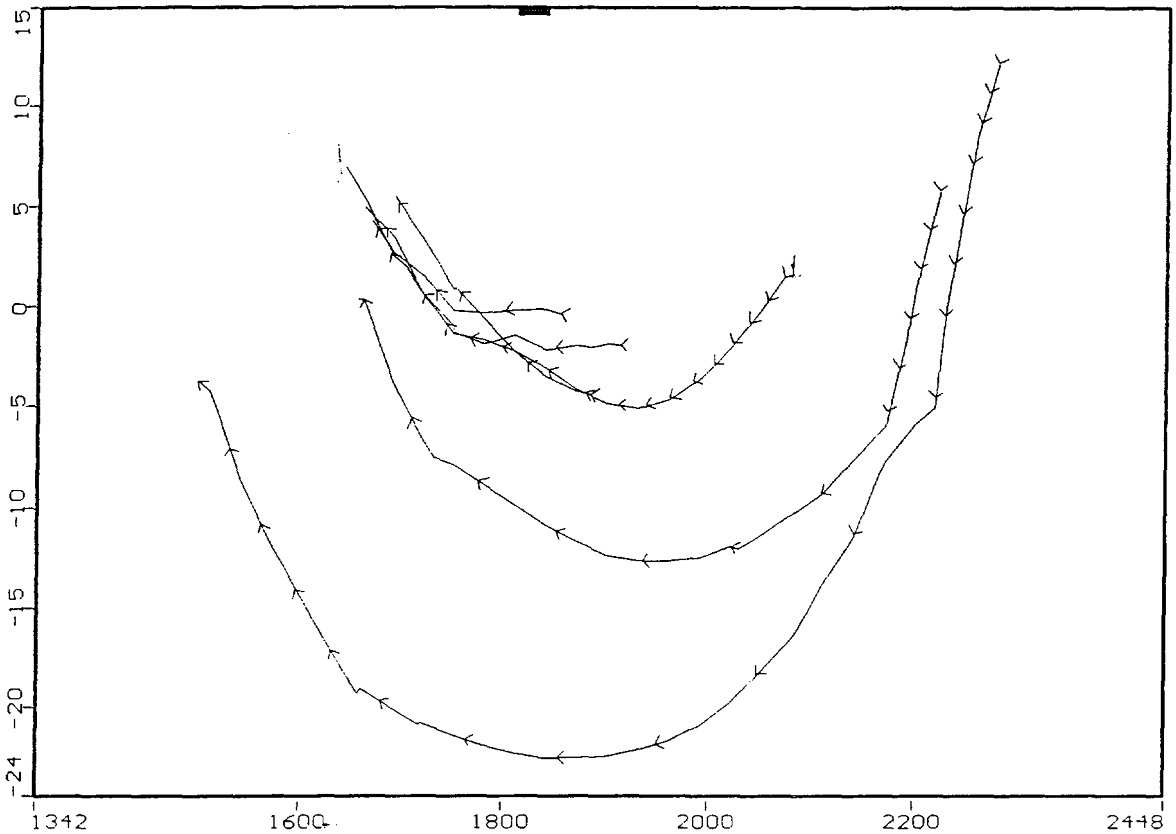
The approximated velocity is determined by observing the retention time of a particle in a thirty foot cell in the middle of the zone of convergence in the center of the model (approximately row 72.) The velocity is then calculated as the distance (30') divided by the retention time (days in 30' cell at row 72.)

RUN 7



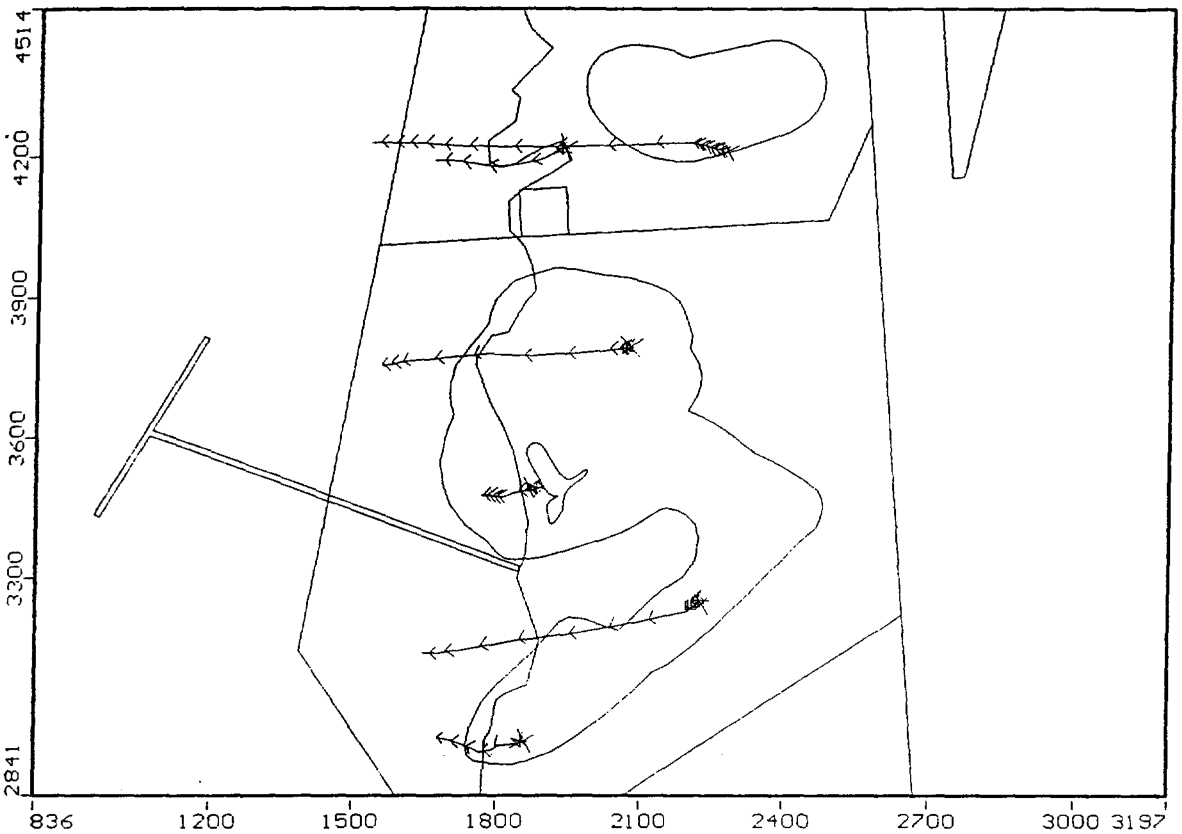
Retec Inc. – Seattle, WA Project: Port Quendall Company Description: No Wall Modeller: SBC 19 May 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Layer: 2

RUN 7



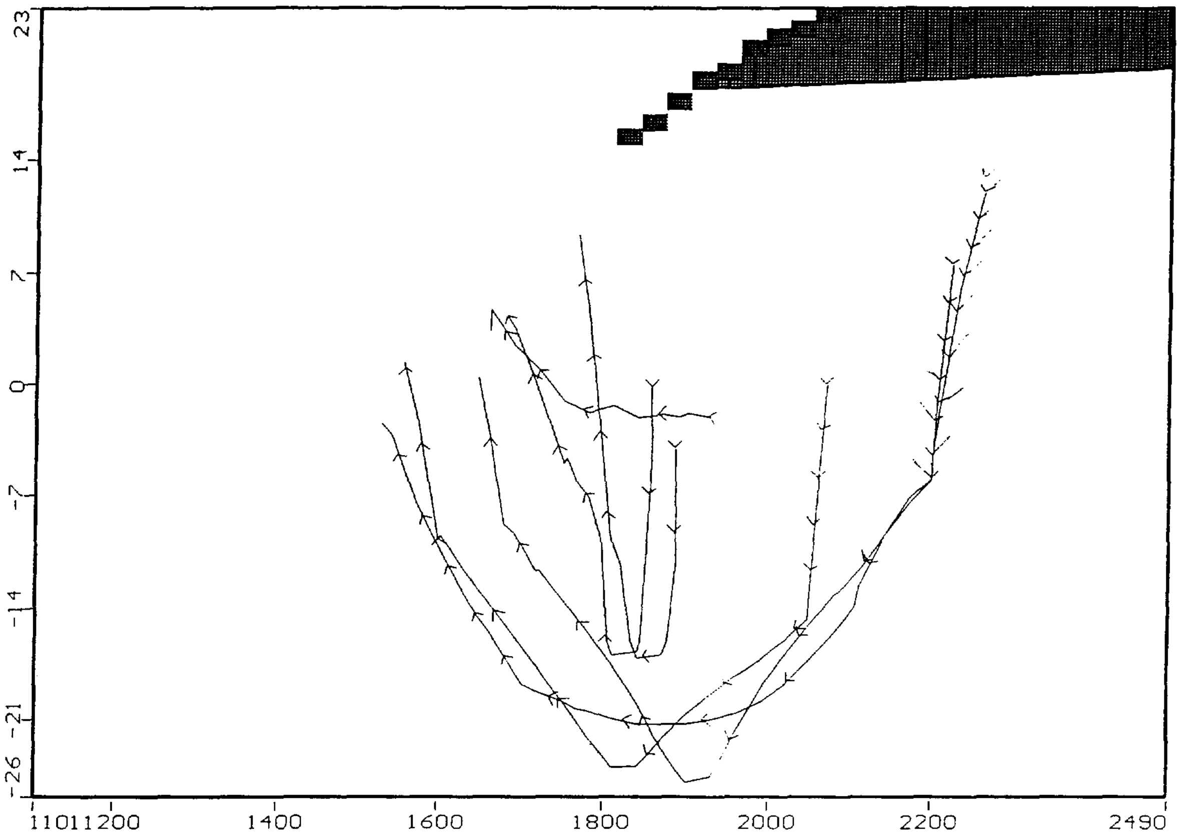
Retec Inc. – Seattle, WA Project: Port Quendall Company Description: No Wall Modeller: SBC 19 May 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Row: 66

RUN 6



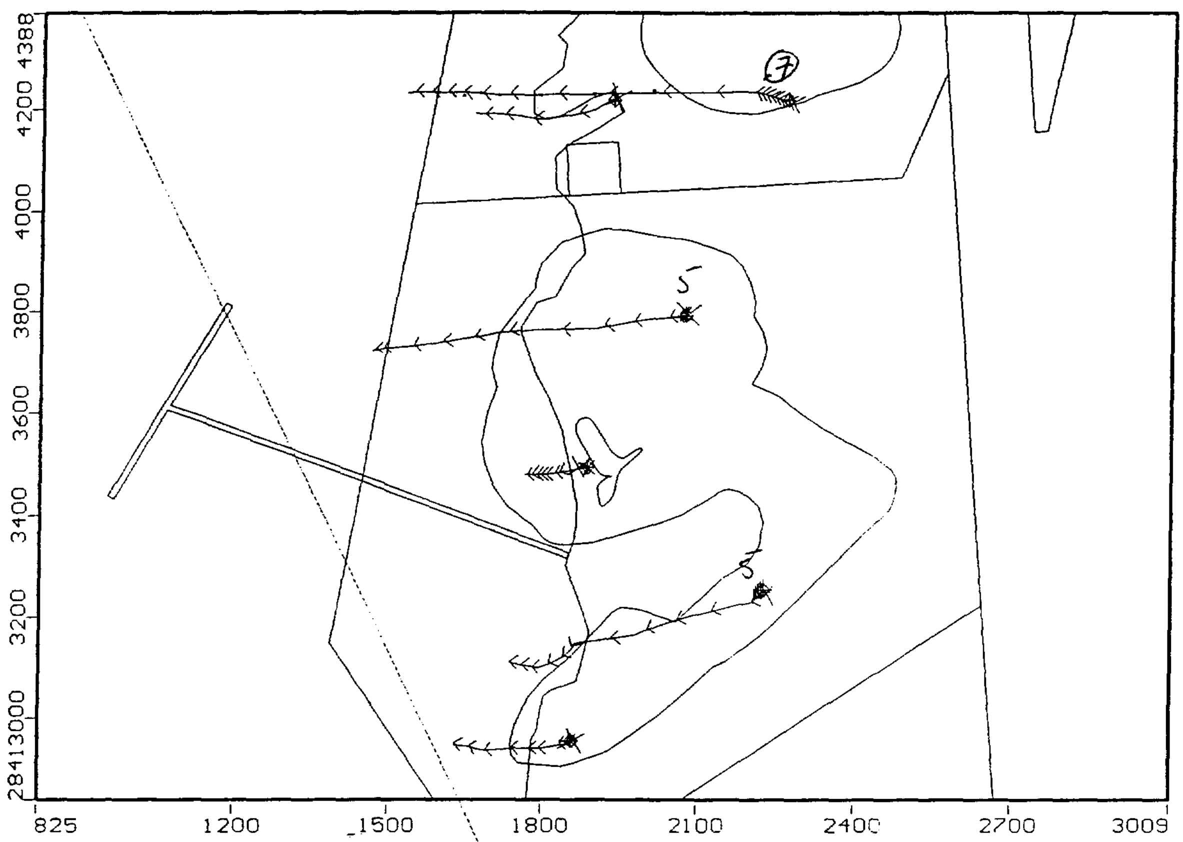
Retec Inc. – Seattle, WA Project: Port Quendall Company Description: Wall – K=2.8e-3 to btm L3 Modeller: SBC 19 May 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Layer: 2

RUN 6



Retec Inc. – Seattle, WA Project: Port Quendall Company Description: Wall – K=2.8e-3 to btm L3 Modeller: SBC 19 May 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Row: 63

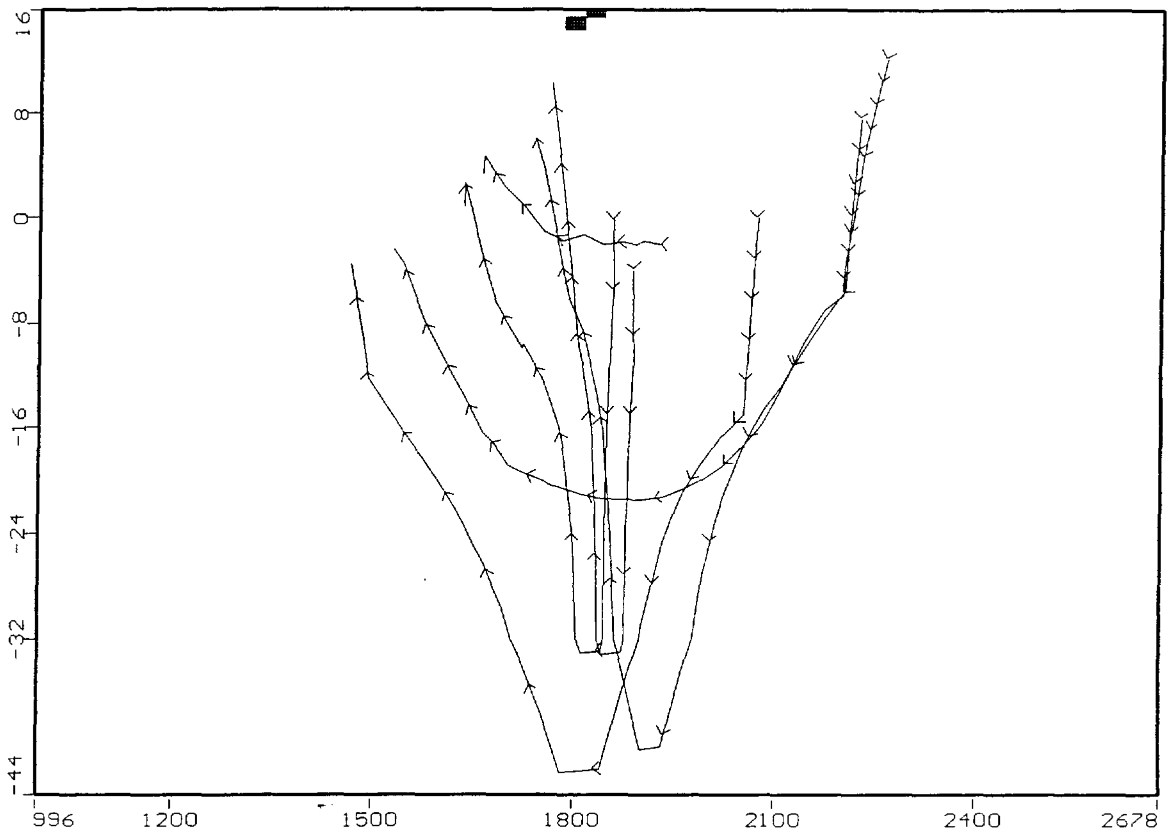
RUN 40



Retec Inc. – Seattle, WA
Project: Port Quendall Company
Description: Wall to 50 ft
Modeller: SBC
3 Jun 97

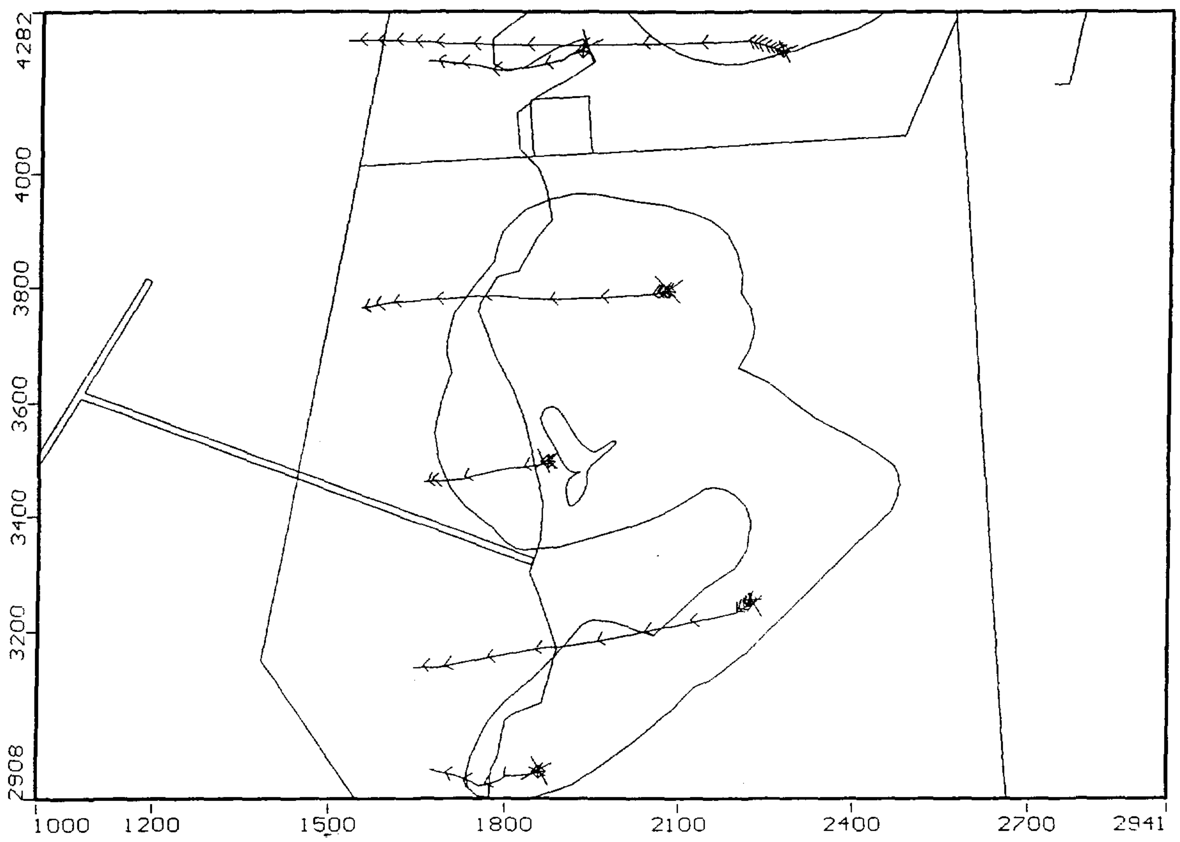
Visual MODFLOW v.2.20, (c) 1995
Waterloo Hydrogeologic Software
NC: 117 NR: 146 NL: 6
Current Layer: 2

RUN 40



Retec Inc. – Seattle, WA Project: Port Quendall Company Description: Wall to 50 ft Modeller: MR / SBC 9 Dec 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Row: 62

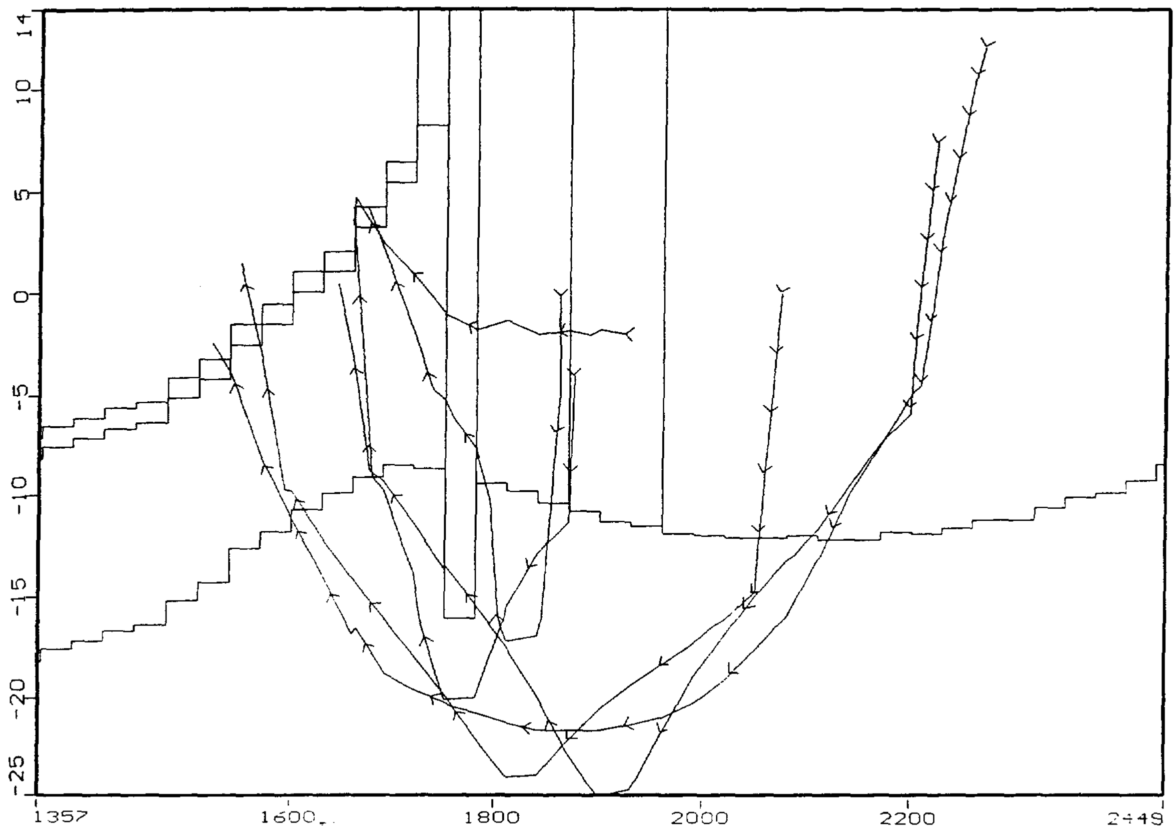
RUN 10



Retec Inc. – Seattle, WA
Project: Port Quendall Company
Description: Wall to 30'
Modeller: SBC
19 May 97

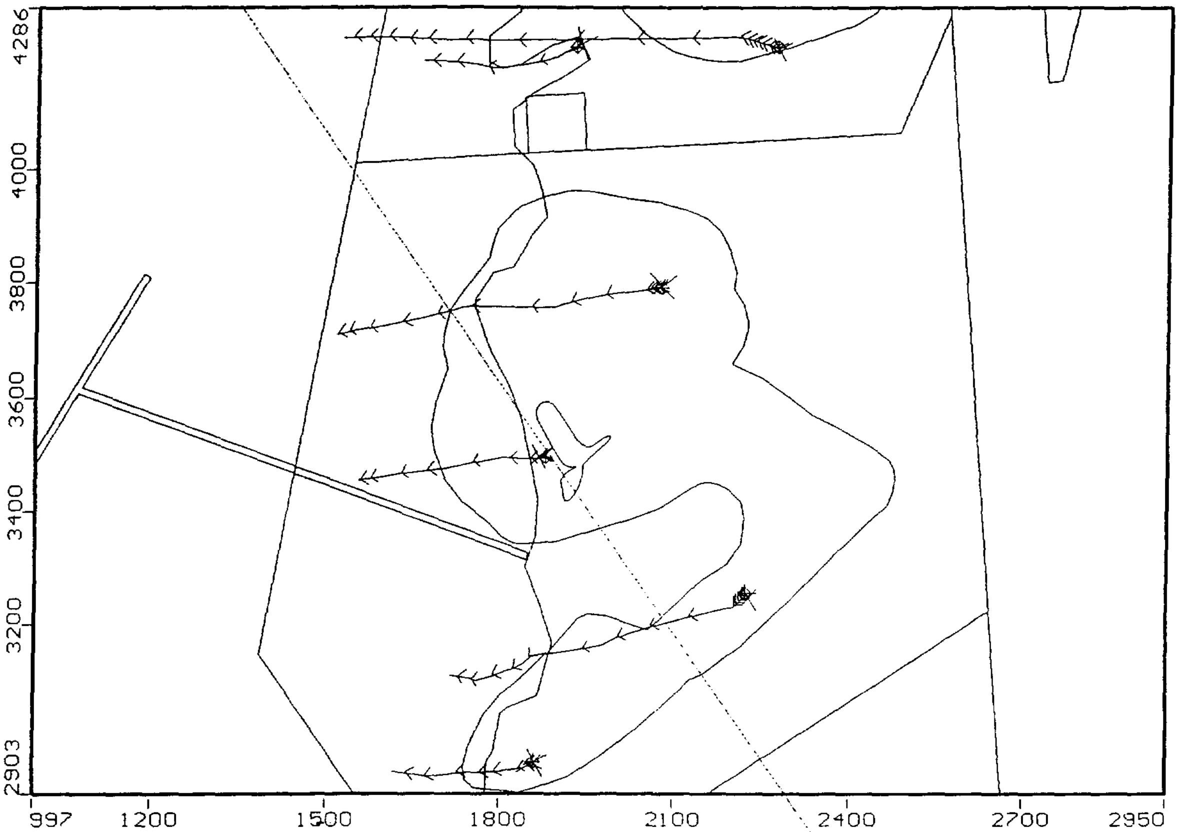
Visual MODFLOW v.2.20, (c) 1995
Waterloo Hydrogeologic Software
NC: 117 NR: 146 NL: 6
Current Layer: 2

RUN 10



Retec Inc. – Seattle, WA Project: Port Quendall Company Description: Wall to 30' Modeller: SBC 19 May 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Row: 69

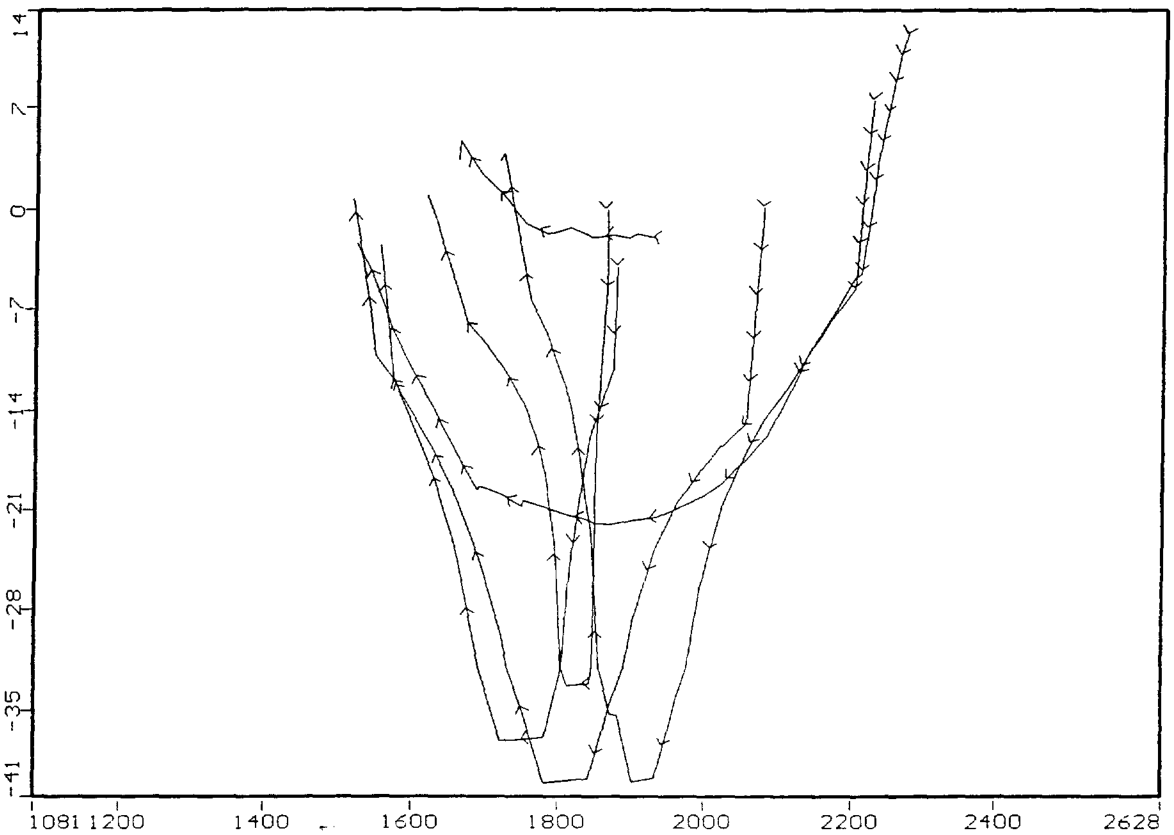
RUN 11



Retec Inc. – Seattle, WA
Project: Port Quendall Company
Description: Nearshore Wall to 50'
Modeller: SBC
20 May 97

Visual MODFLOW v.2.20, (c) 1995
Waterloo Hydrogeologic Software
NC: 117 NR: 146 NL: 6
Current Layer: 2

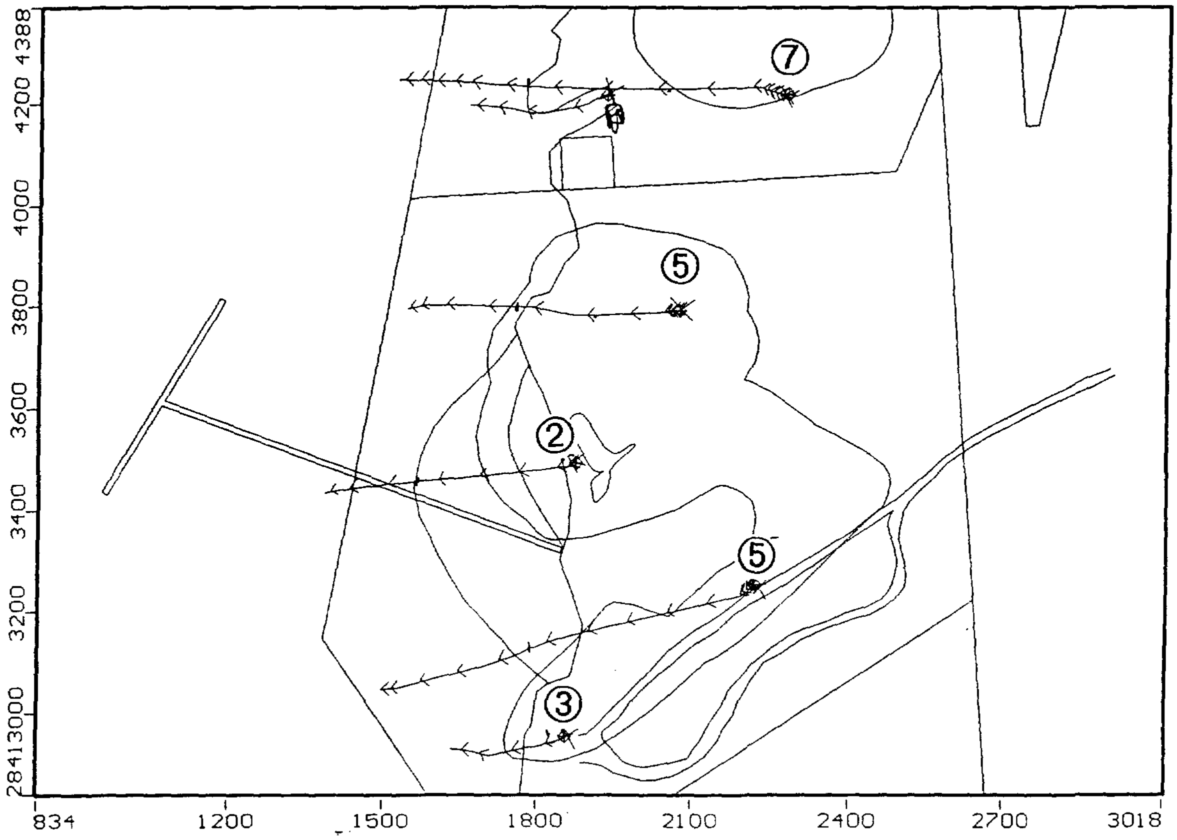
RUN 11



Retec Inc. – Seattle, WA
Project: Port Quendall Company
Description: Nearshore Wall to 50'
Modeller: SBC
20 May 97

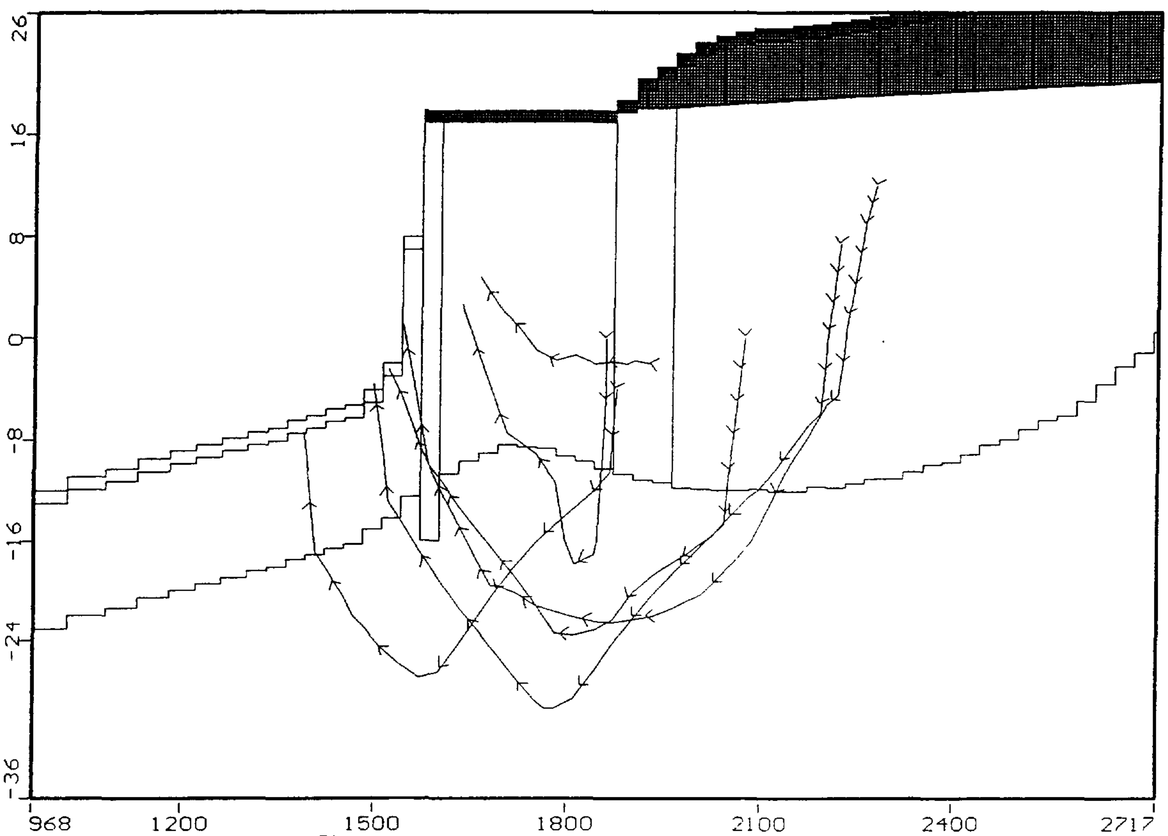
Visual MODFLOW v.2.20, (c) 1995
Waterloo Hydrogeologic Software
NC: 117 NR: 146 NL: 6
Current Row: 65

RUN 25



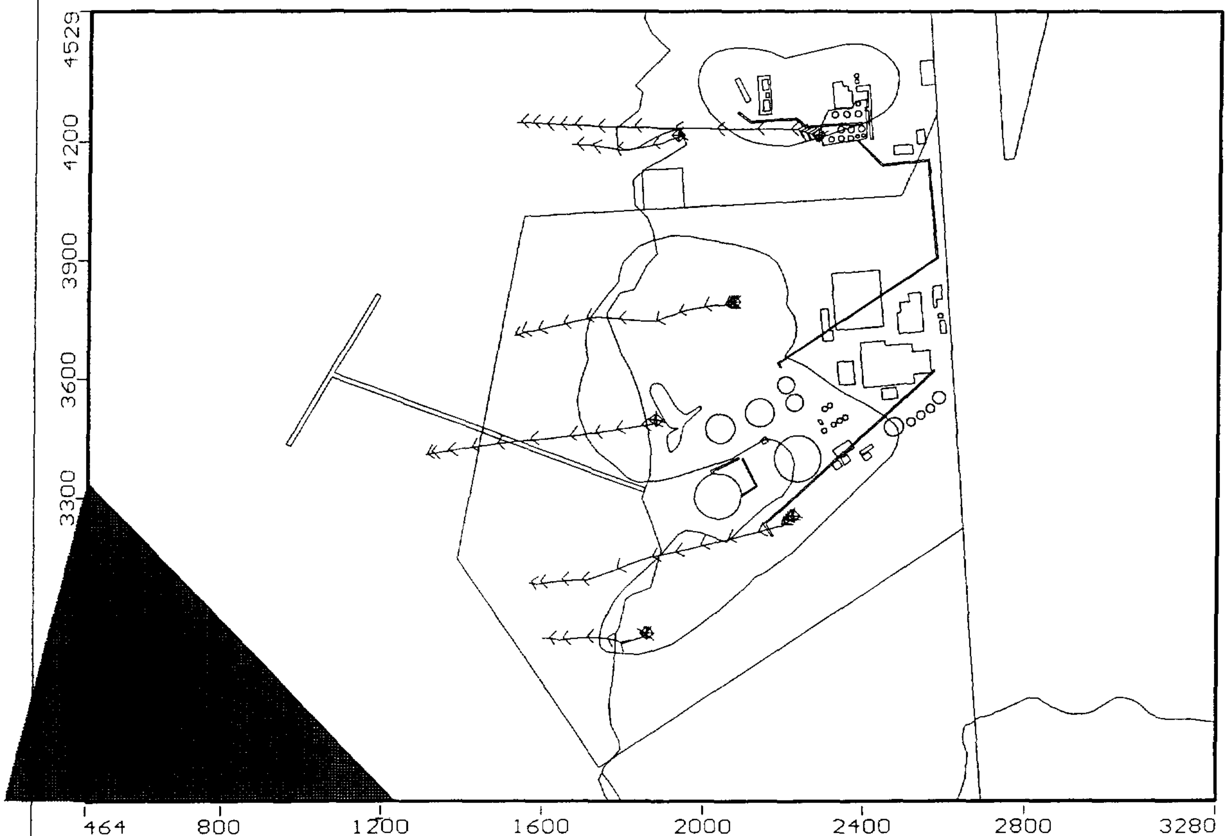
Retec Inc. – Seattle, WA Project: Port Quendall Company Description: Outer Fill(2.9 Ac)30'Wall Modeller: MR / SBC 2 Jun 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Layer: 2

RETEC



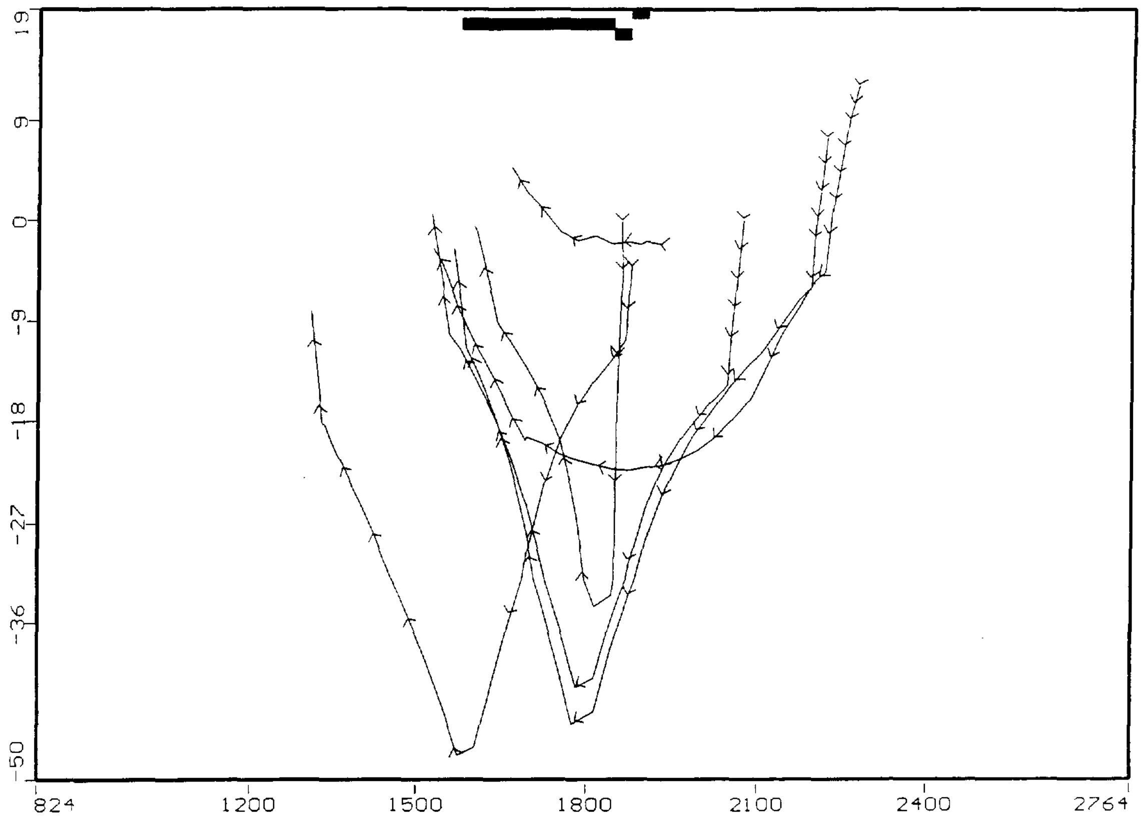
Retec Inc. – Seattle, WA Project: Port Quendall Company Description: Outer Fill(2.9 Ac)30'Wall Modeller: MR / SBC 2 Jun 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Row: 69

RUN 27



Retec Inc. – Seattle, WA Project: Port Quendall Company Description: Outer Fill(2.9 Ac)50'Wall Modeller: MR / SBC 9 Dec 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Layer: 2

RUN 27



Retec Inc. — Seattle, WA Project: Port Quendall Company Description: Outer Fill(2.9 Ac)50'Wall Modeller: MR / SBC 9 Dec 97	Visual MODFLOW v.2.20, (c) 1995 Waterloo Hydrogeologic Software NC: 117 NR: 146 NL: 6 Current Row: 67

Appendix A4

Fate 2 Documentation

FATE2 - A GROUNDWATER CONTAMINATION TRANSPORT SCREENING MODEL

INTRODUCTION

FATE2 is an updated Microsoft EXCEL spreadsheet based implementation of a three-dimensional analytical transient groundwater contaminant transport model first presented in 1987 by P.A. Domenico as published in the article: "*An Analytical model for Multidimensional Transport of a Decaying Contaminant Species*" (J. Hydrology 91, 49-58). The Domenico model is based on the assumption of:

- uniform and constant aquifer properties,
- one dimensional groundwater flow,
- first-order contaminant decay, degradation, or transformation,
- constant contaminant source of rectangular cross-section in the plane perpendicular to groundwater flow.

While the assumed conditions are arguably oversimplifications of any real scenario, the Domenico solution is nevertheless a valuable tool for studying the gross features of contaminant transport behavior and for generating screening level predictions of contaminant transport at sites for which more detailed modeling is not justified.

The spreadsheet model was previously issued as FATE in 1992. Modifications to the FATE spreadsheet as implemented in FATE2 include:

- automation of model calibration to site specific contaminant plume data,
- warning messages which flag input and output parameters which exceed nominal ranges,
- automated calculation of plume attenuation factors, and
- graphical output showing the site specific plume data, receptor location, and the modeled plume attenuation.

Software requirements to run the FATE2 spreadsheet are Microsoft EXCEL 5.0 (or later) with the Solver and Analysis ToolPak Add-Ins installed.

FATE2 - A SPREADSHEET GROUNDWATER CONTAMINANT TRANSPORT MODEL

The spreadsheet FATE2 predicts the maximum centerline concentration in a hydrocarbon plume once steady-state conditions have been reached. The normalized centerline concentration $C(x,y=0,z=0)/C_s$ distribution is predicted by the equation:

$$\frac{C(x,y=0,z=0)}{C_{source}} = \exp\left\{\frac{x}{2\alpha_x}\left[1-\left(1+4\lambda\frac{\alpha_x}{q}\right)^{1/2}\right]\right\}\left(erf\left[\frac{Y}{4\sqrt{\alpha_y x}}\right]\right)\left(erf\left[\frac{Z}{4\sqrt{\alpha_z x}}\right]\right) \tag{1}$$

where:

$C(x,y,z)$	=	solute concentration at location (x,y,z) [mg/l]
C_{source}	=	solute concentration at (x=0,y=0,z=0) [mg/l]
x	=	distance downgradient of source [ft]
α_x	=	longitudinal (x) dispersivity [ft]
α_y	=	transverse (y) dispersivity [ft]
α_z	=	vertical (z) dispersivity [ft]
q	=	groundwater velocity (or specific discharge) [ft/d]

λ	=	attenuation (degradation) coefficient [d^{-1}]
Y	=	source width (perpendicular to groundwater flow in the horizontal plane) [ft]
Z	=	source depth (perpendicular to groundwater flow in the vertical plane) [ft]
erf(η)	=	Error Function evaluated for value (η)

As written, the right-hand-side of Equation (1) is also equivalent to the inverse of the groundwater attenuation factor ($AF(x)=C_s/C_{gw}(x)$)at any distance x from the source.

Equation (1) requires seven site-specific input parameters: α_x, α_y, α_z, q, λ, Y, Z. Of these, three are fixed by hydrologic conditions and the contaminant source distribution. The groundwater velocity, q, is a function of the groundwater gradient, i [m/m], the hydraulic conductivity, K [m/d], and the soil porosity n [m^3/m^3]:

$$q = \frac{Ki}{n} \tag{2}$$

which can be determined at most sites through appropriate aquifer characterization methods. The source dimensions, Y and Z, are estimated from knowledge of the contaminant distribution.

The remaining four parameters, α_x, α_y, α_z, and λ, are usually determined by "fitting" model predictions to site specific data. However, the following information may be used as guidance to verify the reasonableness of parameter values:

Dispersion Coefficients: Based on the USEPA's Background Document for the Groundwater Screening Procedures to Support 40 CFR part 268 Land Disposal Restrictions (1985), initial estimates for dispersion coefficients are:

$$\alpha_x = M_x\, x = 0.1\, x \tag{3}$$

$$\alpha_y = M_y\, \alpha_x = 1/3\, \alpha_x \tag{4}$$

$$\alpha_z = M_z\, \alpha_x = 0.05\alpha_x \tag{5}$$

Thus, the dispersion coefficients are functions of distance, x, from the down gradient edge of the source area and appropriate multiplier factors.

Attenuation Coefficient: The attenuation coefficient, λ, included in Equation (1) is a gross measure of a number of attenuation mechanisms. For aromatic hydrocarbons, biodegradation is likely to be the most significant at sites where aquifer conditions are sufficient to maintain aerobic conditions (typically the presence of dissolved oxygen in groundwater at levels of $\geq$ 2 mg/l upgradient from the source, and the absence of dissolved oxygen within the interior of a solute plume is considered a good indication that biodegradation is likely occurring). Field calibrated macrodegradation rates for aromatic compounds have been reported to be 0.001 - 0.01 [d^{-1}] (see for example: Chiang et al., 1986, "*Data Analysis and Computer Modeling of the Benzene Plume in an Aquifer Beneath a Gas Plant*", in Proc. of NWWA/API Conference on Petroleum hydrocarbons in Groundwater).

More detailed discussion of the input parameters is presented later in this documentation.

In it's current implementation, FATE2 consists of three EXCEL spreadsheets in a single workbook. The first spreadsheet, INPUT, is used to input site specific data, execute EXCEL 5 macros, and provide model output. The second spreadsheet, MODEL, contains the original FATE spreadsheet which is the solution for the normalized maximum centerline concentration in a hydrocarbon plume once steady-state conditions have been reached, based on Domenico's solution. The third spreadsheet, MACROS, contains the EXCEL 5 macros used to calibrated the model and generate model output. Data input, model execution, and results interpretation will each be discussed in the following sections.

MODEL INPUT DATA

Model input data is split into four sections: Flow Model Parameters, Source Data, Monitoring Point Data, and Receptor Data. Data is entered into the model simply by filling in the desired value in the appropriate cell in the INPUT spreadsheet. Parameters which may be set by the user are indicted by **bold type**. All other cells should not be altered, the macros will not function correctly if cell locations are changed.

Flow Model Parameters

Soil Porosity, n (ft^3/ft^3): Porosity is percent of total voids or openings in the soil. It is expressed as the volume of pore space per total volume of the soil. Typical values: $0.25 < n < 0.65$ (ft^3/ft^3).

Hydraulic Conductivity, K (ft/d): Hydraulic Conductivity is a measure of the capacity of the aquifer to transmit water. Typical values: $10^{-4} < K < 10^2$ (ft/d).

Gradient, i (ft/ft): Gradient is the change in hydraulic head per unit of horizontal distance measured in the downgradient direction. Gradient is expressed in foot per foot and also has a directional component. Typical values: $0.001 < I < 0.01$ (ft/ft).

Groundwater Velocity (ft/d): The groundwater (interstitial) velocity is the groundwater flow rate in feet per day and is calculated by $q = K\, i / n$, assuming Darcy's law.

Attenuation and Dispersion: See discussion below.

Source Data

Source Concentration, C_s (mg/l): Concentration of contaminant in groundwater at downgradient edge of source. This should be based on site data (i.e., a monitoring well located at the down gradient edge of the source area) but can be estimated assuming an effective solubility defined by

$$C_s = S_i x_i \tag{6}$$

where: S_i (mg/l) is the solubility limit of the pure compound and x_i is the mole fraction of the compound in the hydrocarbon mixture.

Source Width, Y (ft): The source width is the maximum distance in feet perpendicular to the direction of groundwater flow in the saturated zone impacted by the source area.

Source Thickness, Z (ft): Source thickness reflects the height of the groundwater column in the source area that contains solubilized petroleum constituents. In the case of residual seperate-phsse hydrocarbons trapped beneath the water table, the source thickness is equivalent to the larger of the thickness of the residual contamination zone or the largest observed seasonal variation in the water table.

Farthest Distance, L (ft): Farthest distance from the down gradient edge of the source area to be evaluated, used as a scaling factor in the model output.

Monitoring Point Data

Concentration, $C_{M,i}$ [mg/l]: Concentration of contaminant observed at monitoring point i.

Distance from Source,M_i [ft]: The distance parallel to groundwater flow from the downgradient edge of the source area to the location of monitoring point i.

FATE2 is designed for input of date from one to three monitoring point locations. These monitoring points should be located as close to the centerline of the dissolved contaminant plume as possible and should span the full range of the dissolved phase plume if possible (i.e., should include locations close to but within the down gradient extent of the plume.

Receptor Date

Receptor Distance, R (ft): The receptor distance is the distance in feet from the downgradient edge of the source area to the selected receptor location.

Target Concentration, C^* [mg/l] Selected target exposure point concentration (i.e., MCL, risk-based concentration, or other relevant criteria) which must be met at the receptor location.

The receptor location should be based on the nearest reasonable potential receptor location. This is represented by the nearest of:

- the nearest actual receptor location in the impact water bearing zone,
- the farthest available monitoring location (existing or future), or
- the nearest reasonable future receptor location based on reasonable future land use.

Attenuation and Dispersion Coefficients

Attenuation Coefficient, λ [d^{-1}]: The attenuation coefficient is a measure of the rate at which a compound is lost from a solute plume due to the combined mechanisms of biodegradation, volatilization, and chemical transformation. For aromatic compounds, such as benzene, toluene, and xylenes, aerobic biodegradation is often the dominant mechanism, and attenuation rates of 0.001 to 0.01 [d^{-1}] are reported in the literature for sites where dissolved oxygen concentrations are sufficient to sustain aerobic biodegradation. This parameter is site specific as well as compound specific.

Dispersivity - x direction: This dispersivity is a measure of a plume's tendency to spread horizontally in the direction of groundwater flow as it propagates down gradient from the source (longitudinal dispersion). An initial estimate for the x-dispersivity is 0.1x, where x is the distance in the direction of groundwater flow from the downgradient edge of the source and $M_x = 0.1$ is the x-dispersivity multiplier (USEPA Office of Solid Waste *Background Document for the Groundwater Screening Procedure to Support 40 CFR Part 268 Land Disposal Restrictions,* 1985).

Dispersivity - y direction: This dispersivity is a measure of a plume's tendency to spread horizontally perpendicular to the direction of groundwater flow as it propagates down gradient from the source (lateral dispersion). An initial estimate for the y-dispersivity is x-dispersivity/3, where x-dispersivity is as defined previously and $M_y = 1/3$ is the y-dispersivity multiplier (USEPA Office of Solid Waste *Background Document for the Groundwater Screening Procedure to Support 40 CFR Part 268 Land Disposal Restrictions*, 1985).

Dispersivity - z direction: This dispersivity is a measure of a plume's tendency to spread vertically perpendicular to the direction of groundwater flow as it propagates down gradient from the source (vertical dispersion). An initial estimate for the x-dispersivity is 0.05 x-dispersivity, where x-dispersivity is as defined previously and $M_z = 0.05$ is the z-dispersivity multiplier (USEPA Office of Solid Waste *Background Document for the Groundwater Screening Procedure to Support 40 CFR Part 268 Land Disposal Restrictions*, 1985).

MODEL CALIBRATION

In the current implementation of FATE2, the model is calibrated to site specific data by minimizing the sum of the square of the difference between the predicted and actual attenuation factors at the monitoring point locations by changing either or both the attenuation rate constant, λ, and the dispersivity in the x direction. The dispersivity in the y and z directions are held at their default values as specified above since only centerline plume data is assumed to be available. These values can be changed based on site specific data. Calibration is performed by "clicking" on one of several "buttons" which activate the appropriate macros.

INITIAL - Initialization of the attenuation rate and dispersivities to default values. This step is important in order to ensure proper convergence of the calibration routine and should be performed prior to all model calibration. ($\lambda = 0.001$ [d^{-1}] and $M_x = 0.1$)

CAL - Calibration with respect to attenuation coefficient, λ (i.e., sum of squared difference in minimized by changing λ). More often than not, this will be the primary method of model calibration since the model is more sensitive to changes in this parameter than to changes in dispersivity. Calibration is limited to values, $0.001 < \lambda < 0.01$ [d^{-1}]. (The user should click "OK" after the calibration is complete.)

CAL2 - Calibration with respect to dispersivity in the x direction (i.e., sum of squared difference in minimized by changing M_x or α_x). The model is less sensitive to this parameter. Thus, CAL2 is used for fine tuning of the model. Calibration is limited to values, $0.02 < M_x < 0.5$. (The user should click "OK" after the calibration is complete.)

CAL3 - Calibration with respect to both attenuation rate constant, λ, and dispersivity in the x direction (i.e., sum of squared difference in minimized by changing M_x. (The user should click "OK" after the calibration is complete.)

Please note that previous experience has shown that calibration with respect to the attenuation coefficient is most important while changes in the dispersivity in the x direction can be based on professional judgment and site specific knowledge.

A plot of the predicted normalized centerline concentration as predicted by Equation 1) as a function of distance from the source is located in the INPUT spreadsheet next to the calibration macro buttons to allow visual confirmation that calibration was successful.

MODEL OUTPUT

The basic model output is the normalized concentration (inverse of the attenuation factor, AF), as a function of distance from the down gradient edge of the source area. The macro, PAL, is used to calculate the distance from the source at which the plume has attenuated to the target exposure point concentration, C^*. The macro PAL is automatically run after any calibration, however, it MUST be run manually if model calibration is performed by manually changing input parameters (i.e., the calibration macros are not used).

Plume Atten. Length, PAL [ft]: The plume attenuation length or PAL is the distance away for the source in the direction of groundwater flow at which the normalized groundwater concentration (C/C_S) (under steady-state conditions) equals the normalized target exposure point concentration (C^*/C_S). It is site and compound specific.

PAL - The plume attenuation length is calculated using the macro button, "PAL". Note that a value for PAL will not be shown unless the macro PAL has been run following all initialization any calibration of the model.

The model also outputs the attenuation factor at the input receptor location, Af_r. The predicted concentration at the receptor location can be calculated by divding the source concentration, C_s, by the receptor attenuation factor, Af_r.

Receptor Attenuation Factor, AF_r: The attenuation factor, AFr, is equal to the ratio of the groundwater concentration at the source divided by the groundwater concentration at the receptor location and has values greater than unity. The AF is determined based on the model fit to site specific data.

Finally, the maximum source concentration which is protective of the input receptor is calculated.

Max Source Concentration, C_s*: The maximum source concentration (dissolved concentration at downgradient edge of source) that is protective of a receptor is found by multiplying target exposure point concentration (C^*) by the attenuation factor at the receptor, AF_r:

$$C_S^* = AF_r * C_*. \quad (7)$$

If the nearest reasonable potential receptor is closer to the source than the PAL, than a reduction in source concentration will be required to be protective of the receptor. If the nearest reasonable potential receptor is farther from the source than the PAL, source area reduction may not be required if the source strength is not expected to increase over time (based on contaminant migration from the vadose zone). The calculated value is compared to a user input source area solubility limit. This value should be based on site specific knowledge of the contaminant composition and is the same as the input source area concentration if calculated by Equation (6) above. The symbol ">S" is used to indicate that the calculated maximum source concentration exceeds this solubility limit and thus is physically unattainable.

RESULTS INTERPRETATION

The results of the model are presented both graphically and numerically. Graphically, the results are presented as a plot of attenuation factor, AF, versus distance from the downgradient edge of the source. This plot also shows the site monitoring data, the receptor location, and the location of the plume attenuation length. For sites with more than one contaminant, the largest component PAL value is selected as the PAL_{max}. Any receptor located at a distance greater than the PAL_{max} is not expected to have concentrations greater than the target exposure point concentrations for any contaminant. Therefore, if the selected receptor is located at a distance greater than the PAL_{max}, the target exposure point concentration for this receptor can never be exceeded. If this occurs, source reduction is not required to be protective of the receptor. On the other hand, source reduction is indicated if the nearest receptor location is nearer to the source than the PAL_{max} and the magnitude of source reduction required is indicated by the estimated maximum source concentration, C_s^*.

Appendix A5

Fate 2 Input Parameters

Port Quendall Company
Determination of Representative Aquifer Properties for the Fate and Transport Analysis

Aquifer Properties

Unit	Porosity	Conductivity ft/day	Bulk Density g/cm^3	foc %	% of pathline each unit
Silty fill	0.25	3	1.7	0.29%	0.4
Sand	0.25	40	1.7	0.087%	0.2
Fill/lake sediment	0.25	20	1.7	0.29%	0.4
					1.0

Representative Properties

Porosity	Conductivity ft/day	Bulk Density g/cm^3	foc %	Gradient
0.25	17.2	1.7	0.25%	0.0069

Notes:
The aquifer hydrogeologic properties are taken from the Modflow model presented in this chapter.
A weighted average was applied based on the estimated pathlength for each hydrogeologic unit.
foc: free organic carbon

Calculation of Lambda and Retardation Factors

Constituent	Source	Half-Life (hour)	Half-Life (day)	Type	Lambda (1/day)	log Koc	foc (decimal)	Kd	Bulk Density (g/cm^3)	Total Porosity (decimal)	Retardation Factor (g/cm^3)
Benzene	Aerobic High	384	16	High	0.0433	1.79	0.0022	0.1	1.7	0.25	2
	Aerobic Low	120	5	Low	0.1386						
	Anaerobic High	17280	720	High	0.0010						
	Anaerobic Low	2688	112	Low	0.0062						
Naphthalene	Unacclimated Anaerobic	6192	258	High	0.0027	2.80	0.0022	1.4	1.7	0.25	10
	Unacclimated Aerobic	24	1	Low	0.6931						
Chrysene	Aerobic High	24000	1,000	High	0.0007	5.47	0.0022	650.4	1.7	0.25	4,424
	Aerobic Low	8904	371	Low	0.0019						
	Anaerobic High	96000	4,000	High	0.0002						
	Anaerobic Low	35616	1,484	Low	0.0005						

NOTES:
Half Life: Half lives corresponding to the type of analysis listed in the 'Source' column (e.g. Unaclimated aerobic etc.). Taken from the Handbook of Environmental Degradation Rates, Howard et al, Lewis Publishers, Michigan, 1991.
Lamda: Degradation rate calculated assuming first order degradation. Calculated as: Lamda = -(ln1/2)/Half Life
Log Koc:: Taken from the revised table 3.2 of the Progress Report for Treatability Testing of Sediments and Groundwater for Port Quendall, Retec, May 1997.
foc:: Fraction of organic carbon (foc) based on the data presented in the Hart Crowser Draft Remedial Investigation, October 1996. The foc is a calculated weighted average of the foc for the silty fill(.0029), sand (.00087) and lake sediment units (.0029 -assumed to be the same as silty fill unit).
Kd: Kd = (10^log Koc) * foc
Bulk Density: Assumed parameter
Total Porosity: Assumed parameter
Retardation factor: Retardation factor = (1+kd*(Bulk Density/total porosity)

Evaluation of the Contaminants of Concern
Comparison of Degradation Rates

Degradation Rates						Half Life					
Laboratory Results		(assumes 1st order degradation)				Laboratory Results					
aerobic	aerobic	aerobic		anaerobic		aerobic	aerobic	aerobic		anaerobic	
Amended	Unamended	Lit Low	Lit High	Lit Low	Lit High	Amended	Unamended	Lit High	Lit Low	Lit High	Lit Low
-2.300	-1.300	0.043	0.139	0.001	0.006	0.3	0.5	16.0	5.0	720.0	112.0
-1.380	-1.310	0.035	1.386	0.003	0.028	0.5	0.5	20.0	0.5	258.0	25.0
-0.250	-0.250	0.001	0.002	0.000	0.000	2.8	2.8	1000.0	371.0	4000.0	1484.0

Notes

The Laboratory half lives were taken from the Port Quendall Treatability Study.

The aerobic and anaerobic literature half lives are taken from the Handbook of Environmental Degradation Rates, Howard et al, Lewis Publishers, MI, 1991.

Degradation rates are calculated from the half life based on 1st order degradation (rate (1/day) = .693 / half life (days)):

Port Quendall Company
Source Area Pathline Analysis

Run7 - Base case - no wall

	Elevations ft MSL			Horizontal Projected length		Pathlengths	
	A	B	C	AB	BC	Total	Post Aeration
FSPA 13 ft MSL	13	-21	-4	510	250	761.7	250.6
NSPA -2 ft MSL	-2	-2	5	150	125	125.2	125.2
NSFS 2 ft MSL	2	-4	6	300	125	425.5	125.4
QPNS -4 ft MSL	-4	0	6	50	150	200.3	150.1
SHFS 10 ft MSL	10	-7	2	350	225	575.6	225.2
MCNS 0 ft MSL	0	0	4	90	110	200.1	110.1

Run6 - Upland Wall to 30 feet

	Elevations ft MSL			Horizontal Projected length		Påthlengths	
	A	B	C	AB	BC	Total	Post Aeration
FSPA 13 ft MSL	13	-21	-2	400	350	752.0	350.5
NSPA -2 ft MSL		-2	5		275	275.1	275.1
NSFS 2 ft MSL	2	-24	1.5	250	275	527.5	276.2
QPNS -4 ft MSL	-4	-17	10	50	100	155.2	103.6
SHFS 10 ft MSL	1	-24	2	310	275	587.2	276.2
MCNS 0 ft MSL	0	-17	4	50	150	204.3	151.5

Run25 - Nearshore CDF Wall to 30 feet

	Elevations ft MSL			Horizontal Projected length		Pathlengths	
	A	B	C	AB	BC	Total	Post Aeration
FSPA 13 ft MSL	13	-23	1	400	350	752.4	350.8
NSPA -2 ft MSL		-2	5		275	275.1	275.1
NSFS 2 ft MSL	2	-23	3	260	275	537.4	276.2
QPNS -4 ft MSL	-4	-27	-7	300	200	501.9	201.0
SHFS 10 ft MSL	10	-29	-3.5	475	300	777.7	301.1
MCNS 0 ft MSL	0	-18	3	50	180	234.4	181.2

Notes:
The particle pathlines were determined by estimating the pathlines as triangular in shape from the source area (pt A) to a depth below the wall (pt B) and back upwards to the point of exposure (pt C). The elevations of each point and the horizontal projected length were taken determined from Modlflow Output. The Pythagorean theorem was then applied to determine the total pathlength and the pathlength that occurs after the point aeration.

Appendix A6

Fate 2 Output

Port Quendall
Summary of Fate and Transport Analysis

Run #	Contaminant of Concern	Simulated Source	Simulated Remediation Scenario	Source Concentration mg/L	Degradation Rate 1/day	Plume Attenuation Length ft	Predicted POE Concentration mg/L	Maximum Permissible POC Concentration mg/L
28	benzene	QPNS	30' Upland wall	1.500	0.535	4	1.29E-13	>S
29	benzene	QPNS	30' Upland wall	16.500	0.054	79	9.94E-03	71.35
30	benzene	QPNS	30' Upland wall	1750.000	0.043	205	2.89E+00	26.06
52	benzene	QPNS	30' Upland wall	16.500	0.000	3348	1.01E+01	0.07
31	chrysene	QPNS	30' Upland wall	0.0005	0.0549	20	1.06E-07	>S
32	chrysene	QPNS	30' Upland wall	0.0005	0.0055	187	1.04E-04	0.000140
33	chrysene	QPNS	30' Upland wall	0.0060	0.0007	1147	3.16E-03	0.000056
53	chrysene	QPNS	30' Upland wall	0.0005	0.000	671	3.07E-04	0.000050
34	naphthalene	QPNS	30' Upland wall	32.900	0.516	1	5.17E-12	>S
35	naphthalene	QPNS	30' Upland wall	32.900	0.052	12	2.36E-02	>S
36	naphthalene	QPNS	30' Upland wall	32.900	0.035	18	1.25E-01	>S
54	naphthalene	QPNS	30' Upland wall	32.900	0.000	227	2.02E+01	16.15
39	benzene	MCNS	30' Nearshore wall	1.500	0.535	4	4.38E-19	>S
40	benzene	MCNS	30' Nearshore wall	16.500	0.054	65	7.01E-05	>S
41	benzene	MCNS	30' Nearshore wall	1750.000	0.043	172	2.97E-02	>S
55	benzene	MCNS	30' Nearshore wall	16.500	0.000	1317	1.76E+00	0.40
42	chrysene	MCNS	30' Nearshore wall	0.0005	0.0549	27	1.78E-09	>S
43	chrysene	MCNS	30' Nearshore wall	0.0005	0.0055	116	9.03E-06	0.001600
44	chrysene	MCNS	30' Nearshore wall	0.0060	0.0007	715	5.52E-04	0.000320
56	chrysene	MCNS	30' Nearshore wall	0.0005	0.000	259	5.34E-05	0.000300
45	naphthalene	MCNS	30' Nearshore wall	32.900	0.516	1	2.15E-17	>S
46	naphthalene	MCNS	30' Nearshore wall	32.900	0.052	12	1.78E-04	>S
47	naphthalene	MCNS	30' Nearshore wall	32.900	0.035	17	1.78E-03	>S
57	naphthalene	MCNS	30' Nearshore wall	32.900	0.000	77	3.51E+00	>S

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.535	Min	0.535	0.535
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	1.5
Y - source width perpendicular to groundwater flow [ft]	263
Z - source depth below water table [ft]	18
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	104
Cgw* - Target Concentration [mg/l]	4.30E-02

MODEL CALIBRATION

5) Run Calibration Macros

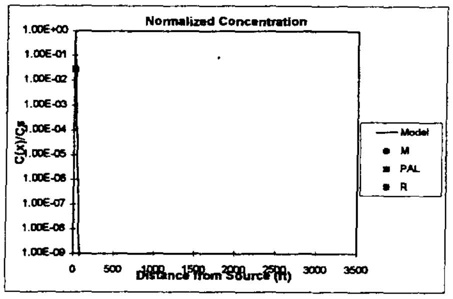
lamda - attenuation rate [1/day] (.001 - .01)	0.5350	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

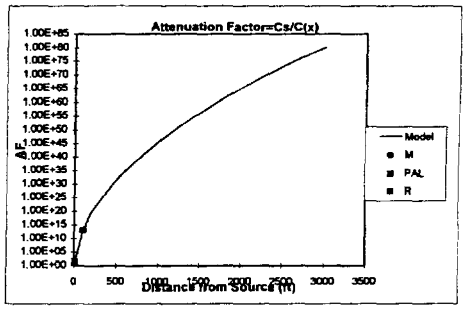
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.49E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.33E-05

PAL

PAL - Plume Attenuation Length [ft]	4
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	104

	Time to Reach Steady State (yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.17E+13
Cr - Concentration at Receptor [mg/l]	1.29E-13
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	1.50

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.0535**	**Min**	0.0535	0.0535
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	**16.5**
Y - source width perpendicular to groundwater flow [ft]	**263**
Z - source depth below water table [ft]	**18**
L - farthest distance to be evaluated from source [ft]	**3000**

NOTES:

This run simulates benzene from the source at qpns reasonable scenario.

3) Input Monitoring Point Data:

Monitoring Point

Cm - concentration at monitoring locations [mg/l]

M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	**104**
Cgw* - Target Concentration [mg/l]	**4.30E-02**

MODEL CALIBRATION

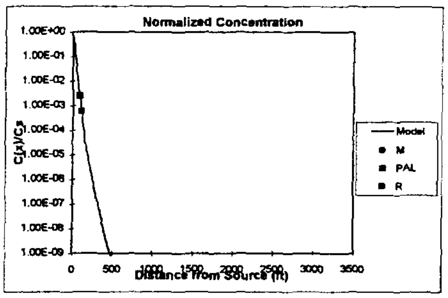
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0535	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

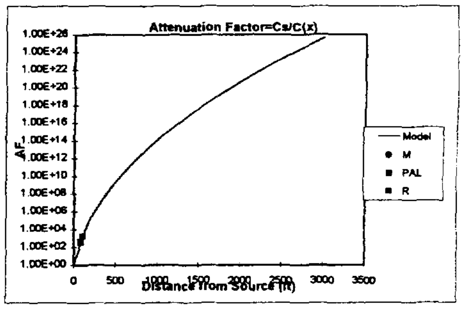
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	3.84E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-9.97E-04

PAL

PAL - Plume Attenuation Length [ft]	79
PAL/L - Scaled Plume Attenuation Length	0.03
R - Distance to Nearest Receptor Location [ft]	104

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation	
AFr - Attenuation Factor at Receptor	1.66E+03
Cr - Concentration at Receptor [mg/l]	9.94E-03
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration	
Cs* - Maximum Source Concentration [mg/l]	71.35
Cs - Source Concentration [mg/l]	16.50

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.043	Min	0.043	0.043
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	1750	>S
Y - source width perpendicular to groundwater flow [ft]	263	
Z - source depth below water table [ft]	18	
L - farthest distance to be evaluated from source [ft]	3000	

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	104
Cgw* - Target Concentration [mg/l]	4.30E-02

MODEL CALIBRATION

5) Run Calibration Macros

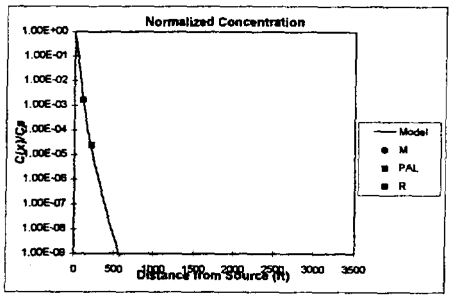
lamda - attenuation rate [1/day] (.001 - .01)	0.0430	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

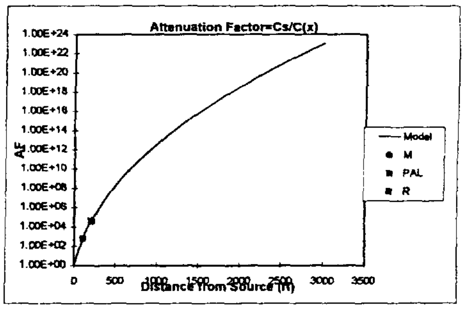
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	4.07E+04
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-6.75E-05

PAL

PAL - Plume Attenuation Length [ft]	205
PAL/L - Scaled Plume Attenuation Length	0.07
R - Distance to Nearest Receptor Location [ft]	104 Receptor is w/in Pl

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	6.06E+02
Cr - Concentration at Receptor [mg/l]	2.89E+00 Exceeds Target
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	26.06
Cs - Source Concentration [mg/l]	1750.00 Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0**	**Min**	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	**16.5**
Y - source width perpendicular to groundwater flow [ft]	**263**
Z - source depth below water table [ft]	**18**
L - farthest distance to be evaluated from source [ft]	**3000**

NOTES:
This run simulates benzene from the source at qpns reasonable scenario.

3) Input Monitoring Point Data:
Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	**104**
Cgw* - Target Concentration [mg/l]	**4.30E-02**

MODEL CALIBRATION

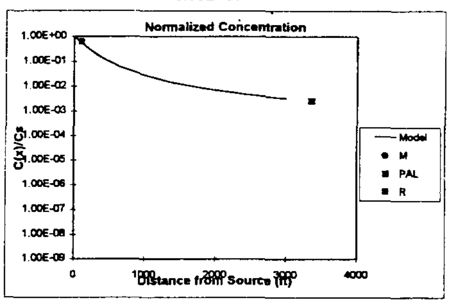
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

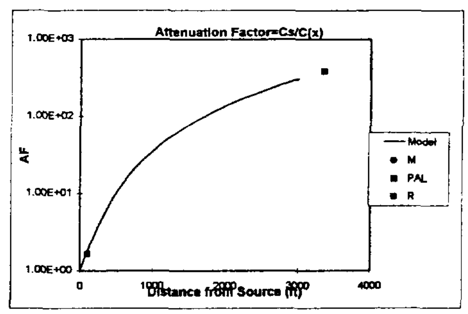
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.84E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.99E-05

PAL

PAL - Plume Attenuation Length [ft]	3348	
PAL/L - Scaled Plume Attenuation Length	1.12	
R - Distance to Nearest Receptor Location [ft]	104	**Receptor is w/in Pl**

Time to Reach Steady State	(yr)
PAL	39
M1	<1
M2	<1
M3	<1
R	1

7) Receptor Attenuation		
AFr - Attenuation Factor at Receptor	1.63E+00	
Cr - Concentration at Receptor [mg/l]	1.01E+01	**Exceeds Target**
Cgw* - Target Concentration [mg/l]	0.043	

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration		
Cs* - Maximum Source Concentration [mg/l]	0.07	
Cs - Source Concentration [mg/l]	16.50	**Source Reduction Rqrd**

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.0549**	**Min**	0.0549	0.055
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	**0.0002**
Y - source width perpendicular to groundwater flow [ft]	**263**
Z - source depth below water table [ft]	**18**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	**104**
Cgw* - Target Concentration [mg/l]	**2.96E-05**

MODEL CALIBRATION

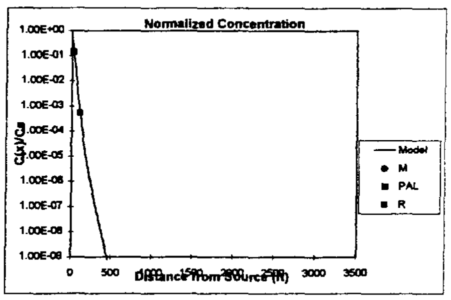
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0549	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

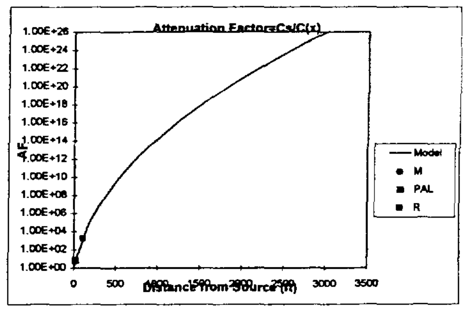
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	6.76E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-2.02E-04

PAL

PAL - Plume Attenuation Length [ft]	20
PAL/L - Scaled Plume Attenuation Length	0.01
R - Distance to Nearest Receptor Location [ft]	104

Time to Reach Steady State	(yr)
PAL	364
M1	<1
M2	<1
M3	<1
R	1102

7) Receptor Attenuation	
AFr - Attenuation Factor at Receptor	1.89E+03
Cr - Concentration at Receptor [mg/l]	1.06E-07
Cgw* - Target Concentration [mg/l]	0.0000296

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	**0.006**
R - Retardation Factor	**4424**

9) Target Source Concentration	
Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	0.0002

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.00549**	**Min**	0.00549	0.00549
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**0.0005**
Y - source width perpendicular to groundwater flow [ft]	**263**
Z - source depth below water table [ft]	**18**
L - farthest distance to be evaluated from source [ft]	**3000**

NOTES:

This run simulates chrysene from the source at QPNS reasonable case scenario.

3) Input Monitoring Point Data:

Monitoring Point

Cm - concentration at monitoring locations [mg/l]

M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**104**
Cgw* - Target Concentration [mg/l]	**2.96E-05**

MODEL CALIBRATION

5) Run Calibration Macros

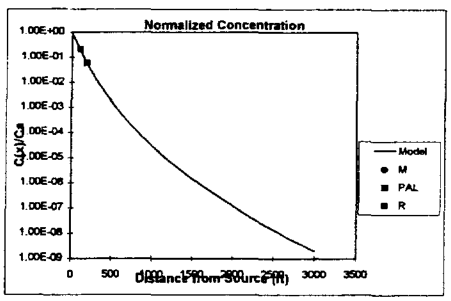
lamda - attenuation rate [1/day] (.001 - .01)	0.0055	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

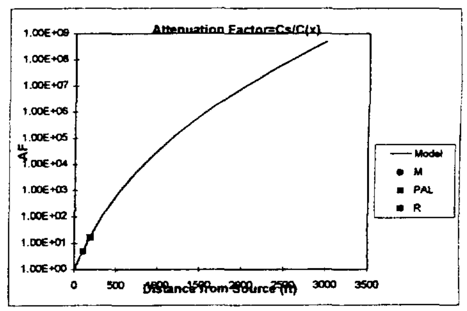
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	1.69E+01
(Cs/Cgw* - AFpel)/(Cs/Cgw*)	7.70E-04

PAL

PAL - Plume Attenuation Length [ft]	187	
PAL/L - Scaled Plume Attenuation Length	0.06	
R - Distance to Nearest Receptor Location [ft]	104	**Receptor is w/in Pl**

Time to Reach Steady State	(yr)
PAL	3492
M1	<1
M2	<1
M3	<1
R	2182

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	4.83E+00	
Cr - Concentration at Receptor [mg/l]	1.04E-04	**Exceeds Target**
Cgw* - Target Concentration [mg/l]	0.0000296	

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**0.006**
R - Retardation Factor	**4424**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.00014	
Cs - Source Concentration [mg/l]	0.00050	**Source Reduction Rqrd**

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.0007	Min	0.0007	0.0007
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	0.006	>S
Y - source width perpendicular to groundwater flow [ft]	263	
Z - source depth below water table [ft]	18	
L - farthest distance to be evaluated from source [ft]	3000	

NOTES:
This run simulates chrysene from the source at QPNS worst case scenario.

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	104
Cgw* - Target Concentration [mg/l]	2.96E-05

MODEL CALIBRATION

5) Run Calibration Macros

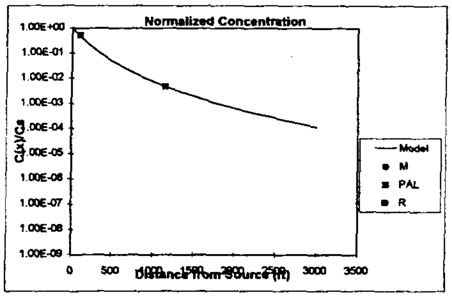
lamda - attenuation rate [1/day] (.001 - .01)	0.0007	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

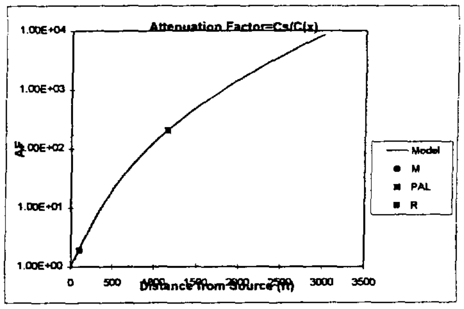
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	2.03E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-2.31E-04

PAL

PAL - Plume Attenuation Length [ft]	1147
PAL/L - Scaled Plume Attenuation Length	0.38
R - Distance to Nearest Receptor Location [ft]	104 Receptor is w/in Pl

Time to Reach Steady State	(yr)
PAL	22621
M1	<1
M2	<1
M3	<1
R	2577

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.90E+00	
Cr - Concentration at Receptor [mg/l]	3.16E-03	Exceeds Target
Cgw* - Target Concentration [mg/l]	0.0000296	

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	0.006
R - Retardation Factor	4424

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.000056	
Cs - Source Concentration [mg/l]	0.0060	Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0.000
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	0.0005
Y - source width perpendicular to groundwater flow [ft]	263
Z - source depth below water table [ft]	18
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	104
Cgw* - Target Concentration [mg/l]	2.96E-05

MODEL CALIBRATION

5) Run Calibration Macros

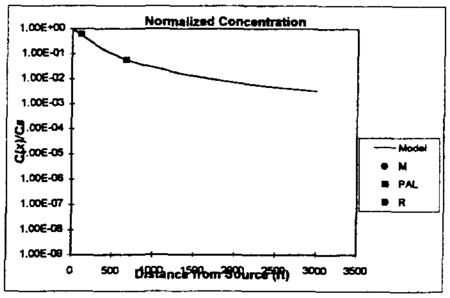
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

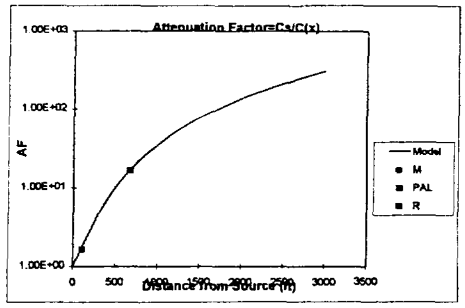
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	1.69E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.68E-04

PAL

PAL - Plume Attenuation Length [ft]	671
PAL/L - Scaled Plume Attenuation Length	0.22
R - Distance to Nearest Receptor Location [ft]	104 **Receptor is w/in Pl**

Time to Reach Steady State	(yr)
PAL	17127
M1	<1
M2	<1
M3	<1
R	2655

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.63E+00
Cr - Concentration at Receptor [mg/l]	3.07E-04 **Exceeds Target**
Cgw* - Target Concentration [mg/l]	0.0000296

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	0.006
R - Retardation Factor	4424

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.00005
Cs - Source Concentration [mg/l]	0.00050 **Source Reduction Rqrd**

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.516**	**Min**	0.516	0.516
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	**32.9** >S
Y - source width perpendicular to groundwater flow [ft]	**263**
Z - source depth below water table [ft]	**18**
L - farthest distance to be evaluated from source [ft]	**3000**

NOTES:

This run simulates naphthalane from the source at QPNS best case scenario

3) Input Monitoring Point Data:

Monitoring Point

Cm - concentration at monitoring locations [mg/l]

M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	**104**
Cgw* - Target Concentration [mg/l]	**9.90E+00**

MODEL CALIBRATION

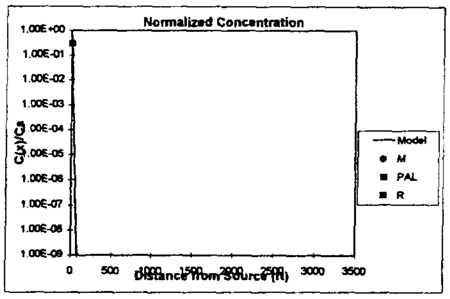
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.5160	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

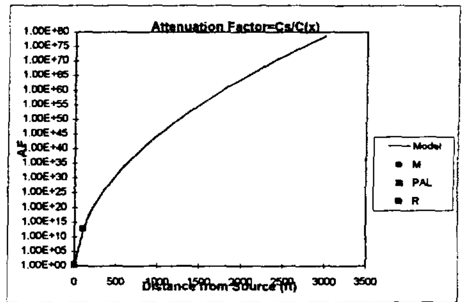
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	3.32E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-5.65E-05

PAL

PAL - Plume Attenuation Length [ft]	1
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	104

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation	
AFr - Attenuation Factor at Receptor	6.36E+12
Cr - Concentration at Receptor [mg/l]	5.17E-12
Cgw* - Target Concentration [mg/l]	9.9

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	**32.9**
R - Retardation Factor	**10**

9) Target Source Concetration	
Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	32.90

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	**Input**		**Min**	**Max**
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.0516**	**Min**	0.0516	0.0516
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:		
Cs - Source Concentration [mg/l]	**32.9**	>S
Y - source width perpendicular to groundwater flow [ft]	**263**	
Z - source depth below water table [ft]	**18**	
L - farthest distance to be evaluated from source [ft]	**3000**	

NOTES:
This run simulates naphthalane from the source at QPNS reasonable scenario

3) Input Monitoring Point Data:
Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	**104**
Cgw* - Target Concentration [mg/l]	**9.90E+00**

MODEL CALIBRATION

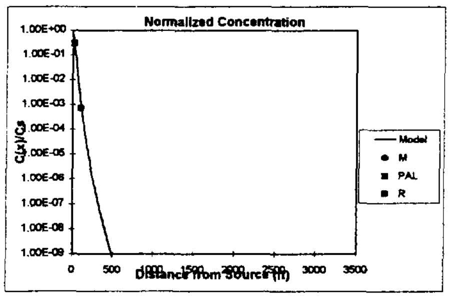
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0516	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

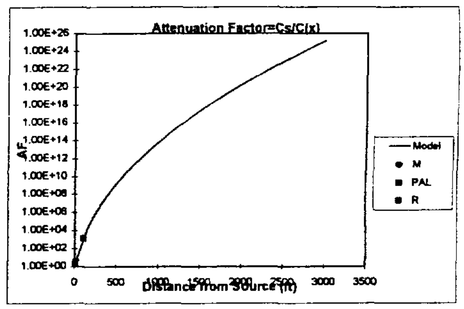
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	3.32E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-2.05E-04

PAL

PAL - Plume Attenuation Length [ft]	12
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	104

	Time to Reach Steady State (yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	3

7) Receptor Attenuation	
AFr - Attenuation Factor at Receptor	1.39E+03
Cr - Concentration at Receptor [mg/l]	2.36E-02
Cgw* - Target Concentration [mg/l]	9.9

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	**32.9**
R - Retardation Factor	**10**

9) Target Source Concetration	
Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	32.90

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.035**	**Min**	0.035	0.035
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**32.9**	>S
Y - source width perpendicular to groundwater flow [ft]	**263**	
Z - source depth below water table [ft]	**18**	
L - farthest distance to be evaluated from source [ft]	**3000**	

NOTES:
This run simulates naphthalane from the source at QPNS worst case scenario

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**104**
Cgw* - Target Concentration [mg/l]	**9.90E+00**

MODEL CALIBRATION

5) Run Calibration Macros

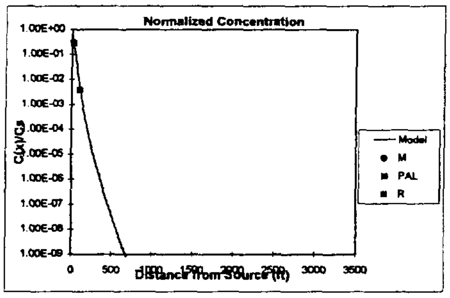
lamda - attenuation rate [1/day] (.001 - .01)	0.0350	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

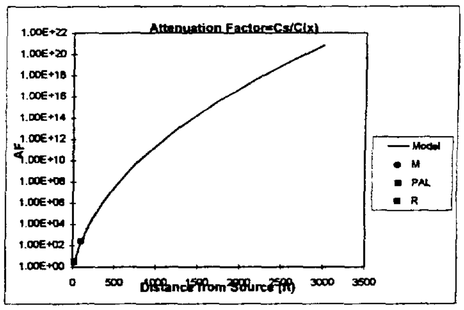
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.32E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-6.64E-04

PAL

PAL - Plume Attenuation Length [ft]	18
PAL/L - Scaled Plume Attenuation Length	0.01
R - Distance to Nearest Receptor Location [ft]	104

	Time to Reach Steady State (yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	3

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	2.63E+02
Cr - Concentration at Receptor [mg/l]	1.25E-01
Cgw* - Target Concentration [mg/l]	9.9

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**32.9**
R - Retardation Factor	**10**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	32.90

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	**Input**		**Min**	**Max**
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:		
Cs - Source Concentration [mg/l]	32.9	>S
Y - source width perpendicular to groundwater flow [ft]	263	
Z - source depth below water table [ft]	18	
L - farthest distance to be evaluated from source [ft]	3000	

NOTES:
This run simulates naphthalane from the source at QPNS reasonable scenario

3) Input Monitoring Point Data:
Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	104
Cgw* - Target Concentration [mg/l]	9.90E+00

MODEL CALIBRATION

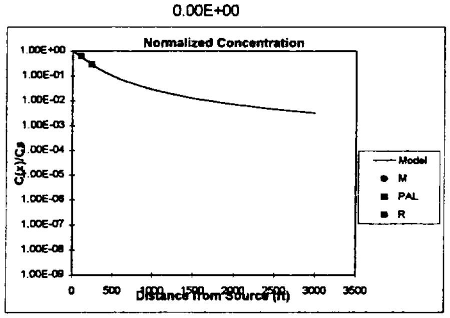
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

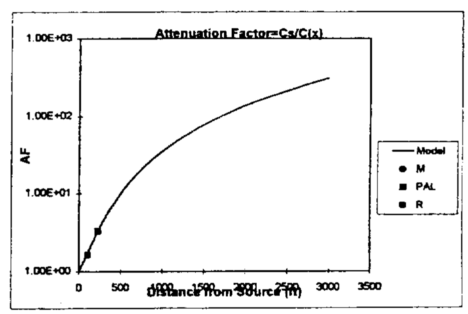
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	3.32E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	3.02E-04

PAL

PAL - Plume Attenuation Length [ft]	227	
PAL/L - Scaled Plume Attenuation Length	0.08	
R - Distance to Nearest Receptor Location [ft]	104	Receptor is w/in Pl

Time to Reach Steady State	(yr)
PAL	13
M1	<1
M2	<1
M3	<1
R	6

7) Receptor Attenuation		
AFr - Attenuation Factor at Receptor	1.63E+00	
Cr - Concentration at Receptor [mg/l]	2.02E+01	Exceeds Target
Cgw* - Target Concentration [mg/l]	9.9	

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	32.9
R - Retardation Factor	10

9) Target Source Concetration		
Cs* - Maximum Source Concentration [mg/l]	16.15	
Cs - Source Concentration [mg/l]	32.90	Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.535	Min	0.535	0.535
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	1.5
Y - source width perpendicular to groundwater flow [ft]	122.3
Z - source depth below water table [ft]	6
L - farthest distance to be evaluated from source [ft]	3000

NOTES:

This run simulates benzene from the source at MCNS best case scenario.

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	181
Cgw* - Target Concentration [mg/l]	4.30E-02

MODEL CALIBRATION

5) Run Calibration Macros

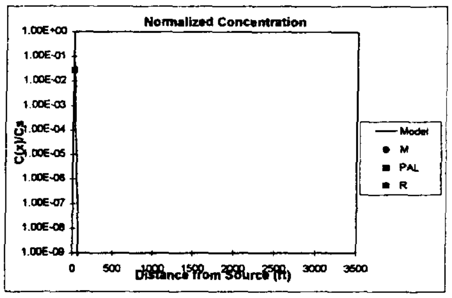
lamda - attenuation rate [1/day] (.001 - .01)	0.5350	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

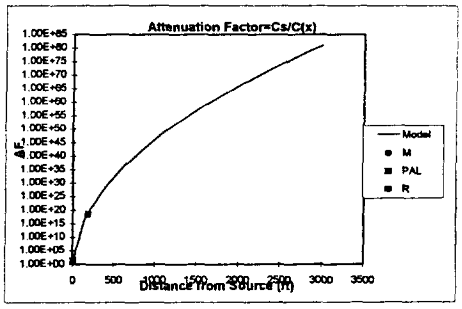
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.49E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-7.82E-04

PAL

PAL - Plume Attenuation Length [ft]	4
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	181

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	3.42E+18
Cr - Concentration at Receptor [mg/l]	4.38E-19
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	1.50

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.0535**	**Min**	0.0535	0.0535
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**16.5**
Y - source width perpendicular to groundwater flow [ft]	**122.3**
Z - source depth below water table [ft]	**6**
L - farthest distance to be evaluated from source [ft]	**3000**

NOTES:
This run simulates benzene from the source at MCNS reasonable scenario.

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**181**
Cgw* - Target Concentration [mg/l]	**4.30E-02**

MODEL CALIBRATION

5) Run Calibration Macros

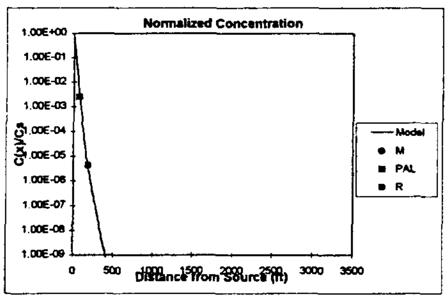
lamda - attenuation rate [1/day] (.001 - .01)	0.0535	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

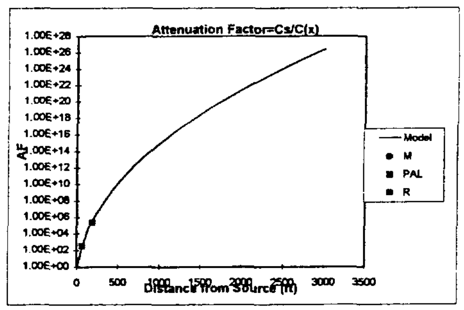
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.84E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-3.47E-04

PAL

PAL - Plume Attenuation Length [ft]	65
PAL/L - Scaled Plume Attenuation Length	0.02
R - Distance to Nearest Receptor Location [ft]	181

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	2.35E+05
Cr - Concentration at Receptor [mg/l]	7.01E-05
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	16.50

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.043	Min	0.043	0.043
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:		
Cs - Source Concentration [mg/l]	1750	>S
Y - source width perpendicular to groundwater flow [ft]	122.3	
Z - source depth below water table [ft]	6	
L - farthest distance to be evaluated from source [ft]	3000	

NOTES:

This run simulates benzene from the source at MCNS worst case scenario.

3) Input Monitoring Point Data:

Monitoring Point

Cm - concentration at monitoring locations [mg/l]

M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	181
Cgw* - Target Concentration [mg/l]	4.30E-02

MODEL CALIBRATION

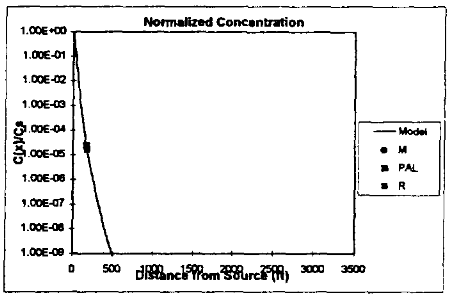
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0430	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

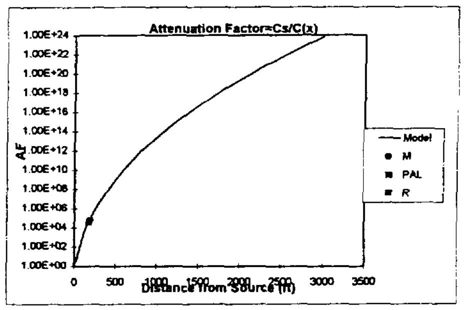
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	4.07E+04
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-2.49E-04

PAL

PAL - Plume Attenuation Length [ft]	172
PAL/L - Scaled Plume Attenuation Length	0.06
R - Distance to Nearest Receptor Location [ft]	181

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation	
AFr - Attenuation Factor at Receptor	5.88E+04
Cr - Concentration at Receptor [mg/l]	2.97E-02
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration	
Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	1750.00

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	16.5
Y - source width perpendicular to groundwater flow [ft]	122.3
Z - source depth below water table [ft]	6
L - farthest distance to be evaluated from source [ft]	3000

NOTES:

This run simulates benzene from the source at MCNS reasonable scenario.

3) Input Monitoring Point Data:

Monitoring Point

Cm - concentration at monitoring locations [mg/l]

M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	181
Cgw* - Target Concentration [mg/l]	4.30E-02

MODEL CALIBRATION

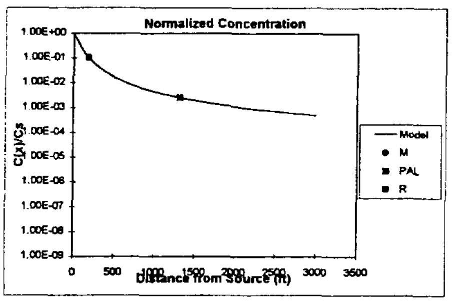
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

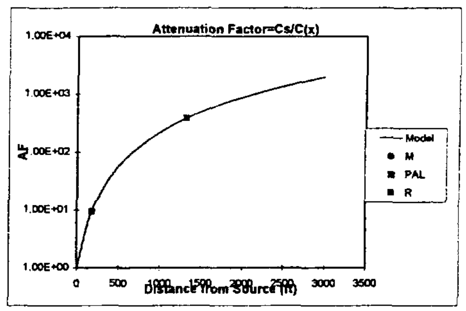
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.84E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	7.97E-04

PAL

PAL - Plume Attenuation Length [ft]	1317	
PAL/L - Scaled Plume Attenuation Length	0.44	
R - Distance to Nearest Receptor Location [ft]	181	Receptor is w/in Pl

Time to Reach Steady State	(yr)
PAL	15
M1	<1
M2	<1
M3	<1
R	2

7) Receptor Attenuation		
AFr - Attenuation Factor at Receptor	9.36E+00	
Cr - Concentration at Receptor [mg/l]	1.76E+00	Exceeds Target
Cgw* - Target Concentration [mg/l]	0.043	

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration		
Cs* - Maximum Source Concentration [mg/l]	0.40	
Cs - Source Concentration [mg/l]	16.50	Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.0549	Min	0.0549	0.05490
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	0.0005
Y - source width perpendicular to groundwater flow [ft]	122.3
Z - source depth below water table [ft]	6
L - farthest distance to be evaluated from source [ft]	3000

NOTES:
This run simulates chrysene from the source at MCNS best case scenario.

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	181
Cgw* - Target Concentration [mg/l]	2.96E-05

MODEL CALIBRATION

5) Run Calibration Macros

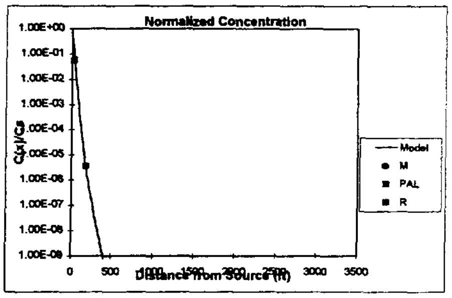
lamda - attenuation rate [1/day] (.001 - .01)	0.0549	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

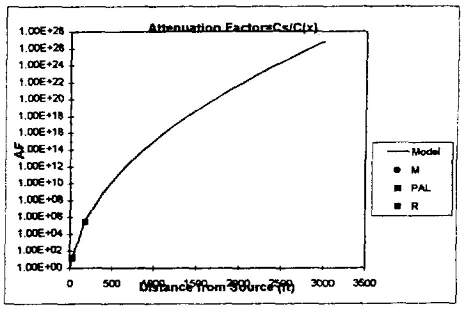
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	1.69E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.74E-05

PAL

PAL - Plume Attenuation Length [ft]	27
PAL/L - Scaled Plume Attenuation Length	0.01
R - Distance to Nearest Receptor Location [ft]	181

Time to Reach Steady State	(yr)
PAL	462
M1	<1
M2	<1
M3	<1
R	1509

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	2.80E+05
Cr - Concentration at Receptor [mg/l]	1.78E-09
Cgw* - Target Concentration [mg/l]	0.0000296

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	0.006
R - Retardation Factor	4424

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	0.0005

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.00549**	**Min**	0.00549	0.0055
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**0.0005**
Y - source width perpendicular to groundwater flow [ft]	**122.3**
Z - source depth below water table [ft]	**6**
L - farthest distance to be evaluated from source [ft]	**3000**

NOTES:

This run simulates chrysene from the source at MCNS reasonable case scenario.

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**181**
Cgw* - Target Concentration [mg/l]	**2.96E-05**

MODEL CALIBRATION

5) Run Calibration Macros

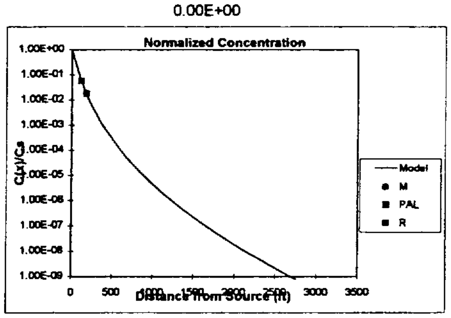
lamda - attenuation rate [1/day] (.001 - .01)	0.0055	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

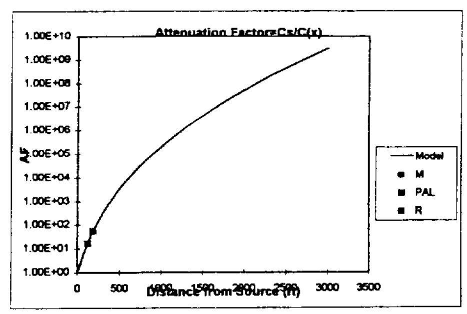
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	1.69E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	1.56E-04

PAL

PAL - Plume Attenuation Length [ft]	116
PAL/L - Scaled Plume Attenuation Length	0.04
R - Distance to Nearest Receptor Location [ft]	181

	Time to Reach Steady State (yr)
PAL	2388
M1	<1
M2	<1
M3	<1
R	3409

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	5.54E+01
Cr - Concentration at Receptor [mg/l]	9.03E-06
Cgw* - Target Concentration [mg/l]	0.0000296

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**0.006**
R - Retardation Factor	**4424**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.0016
Cs - Source Concentration [mg/l]	0.0005

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.0004	Min	0.0004	0.0004
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:		
Cs - Source Concentration [mg/l]	0.006	>S
Y - source width perpendicular to groundwater flow [ft]	122.3	
Z - source depth below water table [ft]	6	
L - farthest distance to be evaluated from source [ft]	3000	

NOTES:

This run simulates chrysene from the source at MCNS worst case scenario.

3) Input Monitoring Point Data:

Monitoring Point

Cm - concentration at monitoring locations [mg/l]

M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	181
Cgw* - Target Concentration [mg/l]	2.96E-05

MODEL CALIBRATION

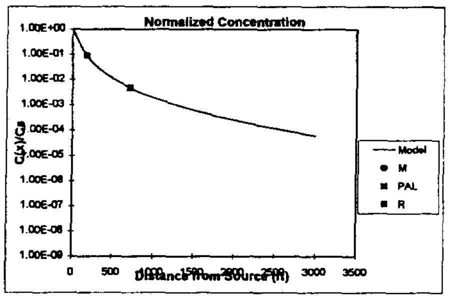
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0004	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

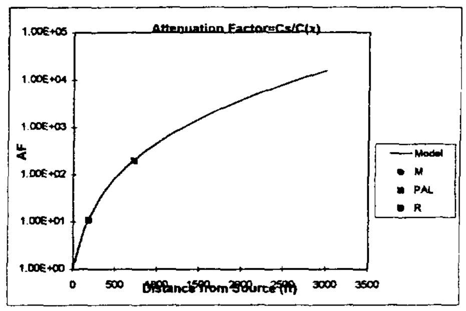
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	2.03E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-8.23E-05

PAL

PAL - Plume Attenuation Length [ft]	715	
PAL/L - Scaled Plume Attenuation Length	0.24	
R - Distance to Nearest Receptor Location [ft]	181	Receptor is w/in Pl

Time to Reach Steady State	(yr)
PAL	16391
M1	<1
M2	<1
M3	<1
R	4486

7) Receptor Attenuation		
AFr - Attenuation Factor at Receptor	1.09E+01	
Cr - Concentration at Receptor [mg/l]	5.52E-04	Exceeds Target
Cgw* - Target Concentration [mg/l]	0.0000296	

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	0.006
R - Retardation Factor	4424

9) Target Source Concetration		
Cs* - Maximum Source Concentration [mg/l]	0.00032	
Cs - Source Concentration [mg/l]	0.0060	Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0**	**Min**	0	0.000
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	**0.0005**
Y - source width perpendicular to groundwater flow [ft]	**122.3**
Z - source depth below water table [ft]	**6**
L - farthest distance to be evaluated from source [ft]	**3000**

NOTES:

This run simulates chrysene from the source at MCNS reasonable case scenario.

3) Input Monitoring Point Data:

Monitoring Point

Cm - concentration at monitoring locations [mg/l]

M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	**181**
Cgw* - Target Concentration [mg/l]	**2.96E-05**

MODEL CALIBRATION

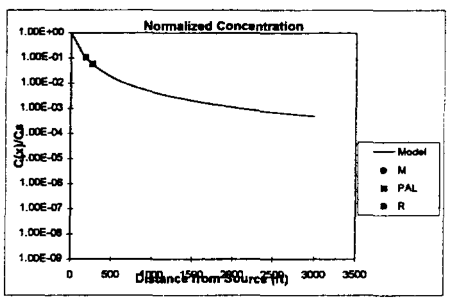
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

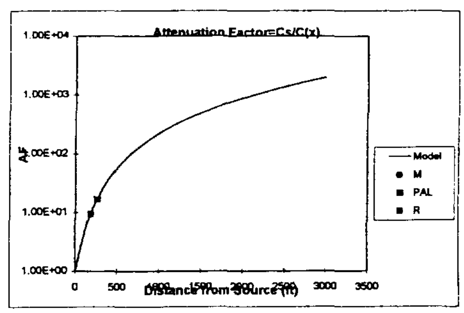
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	1.69E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	2.92E-04

PAL

PAL - Plume Attenuation Length [ft]	259	
PAL/L - Scaled Plume Attenuation Length	0.09	
R - Distance to Nearest Receptor Location [ft]	181	**Receptor is w/in Pl**

Time to Reach Steady State	(yr)
PAL	6611
M1	<1
M2	<1
M3	<1
R	4621

7) Receptor Attenuation		
AFr - Attenuation Factor at Receptor	9.36E+00	
Cr - Concentration at Receptor [mg/l]	5.34E-05	**Exceeds Target**
Cgw* - Target Concentration [mg/l]	0.0000296	

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	**0.006**
R - Retardation Factor	**4424**

9) Target Source Concetration		
Cs* - Maximum Source Concentration [mg/l]	0.0003	
Cs - Source Concentration [mg/l]	0.0005	**Source Reduction Rqrd**

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.516**	**Min**	0.516	0.516
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**32.9**	>S
Y - source width perpendicular to groundwater flow [ft]	**122.3**	
Z - source depth below water table [ft]	**6**	
L - farthest distance to be evaluated from source [ft]	**3000**	

NOTES:
This run simulates naphthalane from the source at MCNS best case scenario

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**181**
Cgw* - Target Concentration [mg/l]	**9.90E+00**

MODEL CALIBRATION

5) Run Calibration Macros

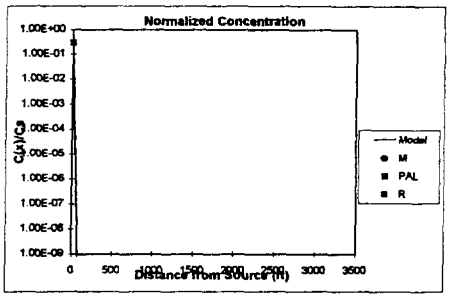
lamda - attenuation rate [1/day] (.001 - .01)	0.5160	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

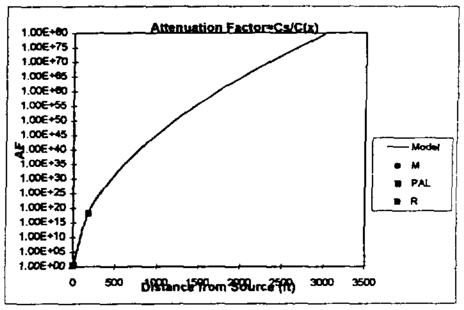
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.32E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-4.83E-05

PAL

PAL - Plume Attenuation Length [ft]	1
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	181

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.53E+18
Cr - Concentration at Receptor [mg/l]	2.15E-17
Cgw* - Target Concentration [mg/l]	9.9

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**32.9**
R - Retardation Factor	**10**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	32.90

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.0516	Min	0.0516	0.0516
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:		
Cs - Source Concentration [mg/l]	32.9	>S
Y - source width perpendicular to groundwater flow [ft]	122.3	
Z - source depth below water table [ft]	6	
L - farthest distance to be evaluated from source [ft]	3000	

NOTES:
This run simulates naphthalane from the source at MCNS reasonable scenario

3) Input Monitoring Point Data:
Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	181
Cgw* - Target Concentration [mg/l]	9.90E+00

MODEL CALIBRATION

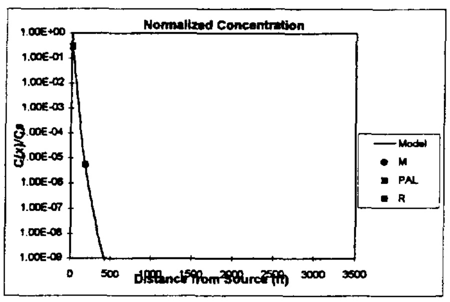
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0516	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

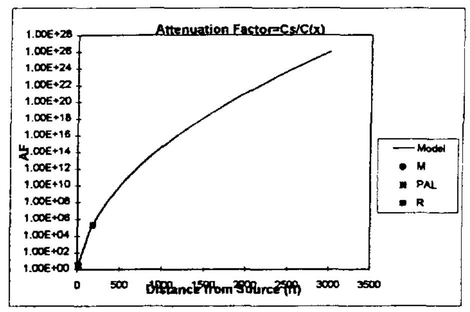
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	3.32E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-3.11E-04

PAL

PAL - Plume Attenuation Length [ft]	12
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	181

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	4

7) Receptor Attenuation	
AFr - Attenuation Factor at Receptor	1.85E+05
Cr - Concentration at Receptor [mg/l]	1.78E-04
Cgw* - Target Concentration [mg/l]	9.9

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	32.9
R - Retardation Factor	10

9) Target Source Concetration	
Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	32.90

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.035	Min	0.035	0.035
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	32.9 >S
Y - source width perpendicular to groundwater flow [ft]	122.3
Z - source depth below water table [ft]	6
L - farthest distance to be evaluated from source [ft]	3000

NOTES:
This run simulates naphthalane from the source at MCNS worst case scenario

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	181
Cgw* - Target Concentration [mg/l]	9.90E+00

MODEL CALIBRATION

5) Run Calibration Macros

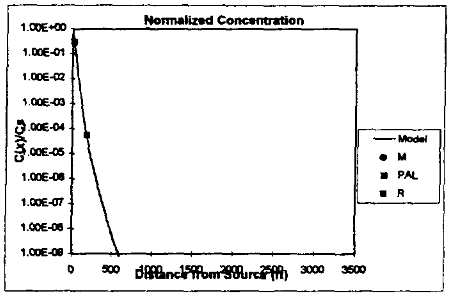
lamda - attenuation rate [1/day] (.001 - .01)	0.0350	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

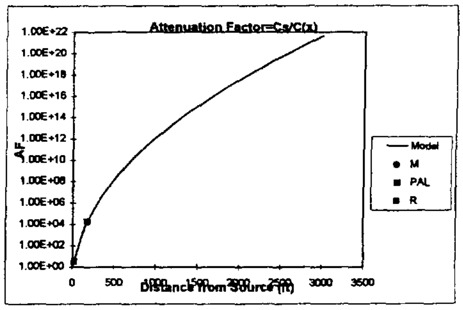
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.32E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-2.27E-05

PAL

PAL - Plume Attenuation Length [ft]	17
PAL/L - Scaled Plume Attenuation Length	0.01
R - Distance to Nearest Receptor Location [ft]	181

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	4

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.85E+04
Cr - Concentration at Receptor [mg/l]	1.78E-03
Cgw* - Target Concentration [mg/l]	9.9

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	32.9
R - Retardation Factor	10

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	32.90

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	32.9	>S
Y - source width perpendicular to groundwater flow [ft]	122.3	
Z - source depth below water table [ft]	6	
L - farthest distance to be evaluated from source [ft]	3000	

NOTES:
This run simulates naphthalene from the source at MCNS reasonable scenario

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	181
Cgw* - Target Concentration [mg/l]	9.90E+00

MODEL CALIBRATION

5) Run Calibration Macros

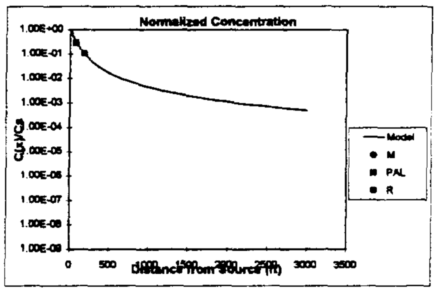
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

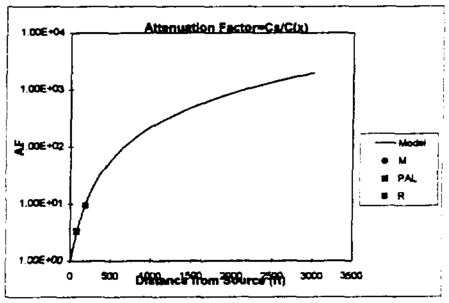
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.32E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	4.64E-05

PAL

PAL - Plume Attenuation Length [ft]	77
PAL/L - Scaled Plume Attenuation Length	0.03
R - Distance to Nearest Receptor Location [ft]	181

Time to Reach Steady State	(yr)
PAL	4
M1	<1
M2	<1
M3	<1
R	10

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	9.36E+00
Cr - Concentration at Receptor [mg/l]	3.51E+00
Cgw* - Target Concentration [mg/l]	9.9

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	32.9
R - Retardation Factor	10

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	32.90

Appendix A7

Dewatering Analysis

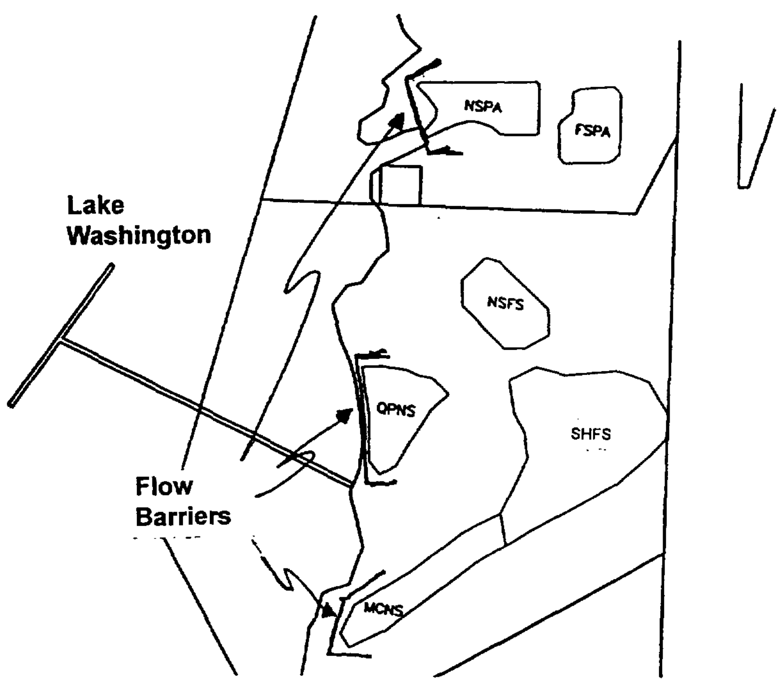
Table 3-1 Dewatering Analysis Results

Area to be Dewatered	Depressed Water Table Elevation - ft MSL		Pumping Rates - GPM	
	at West end of area	at East end of area	Without a Flow Barrier	With a Flow Barrier
NSPA	6	9	40	26
FSPA	5	5	10	NA
NSFS	2	11	34	NA
QPNS	-1	9	82	24
SHFS	11	18	25	NA
MCNS	0	11	67	32

Notes:
NSPA - Near Shore Process Area
FSPA - Far Shore Process Area
NSFS - North Sump Far Shore
QPNS - Quendall Pond Near Shore Area
SHFS - Still House Far Shore Area
MCNS - May Creek Near Shore Area

The depressed water table elevations were assigned to the excavation areas as con: Budget feature of Modflow was then used to evaluate an approximate pumping ra water table elevation.

If a temporary flow barrier was being considered during dewatering, then the dew: for the scenario that included and excluded a relatively impervious barrier to a dep The flow barriers were modelled along the lake side of the excavation areas and inl the excavation areas the to the East approximately 80 feet.

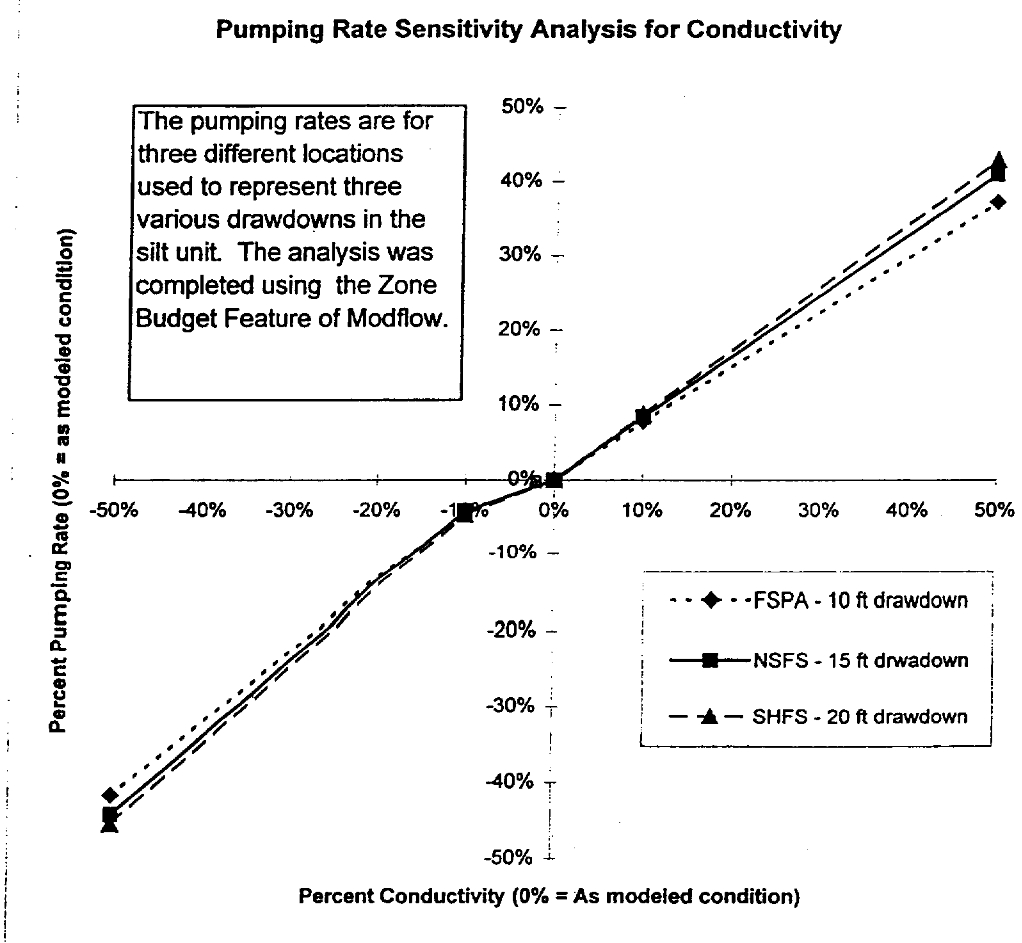


Port Quendall Company
Pumping Rate Sensitivity Analysis for Conductivity

Well Location	Pumping Rates in ft^3/day FSPA	NSFS	SHFS	Silt Conductivity Kx/Ky	Kz
Ksilt decr 50%	1348	2282	1896	1.5	0.03
Ksilt decr 10%	2214	3919	3316	2.7	0.054
as is	2312	4090	3478	3	0.06
Ksilt incr 10%	2492	4435	3783	3.3	0.66
Ksilt incr 50%	3173	5767	4971	4.5	0.09

Pumping Rates as compared to base case

Well Location	FSPA - 1	NSFS - 1	SHFS - 2
Ksilt decr 50%	-42%	-44%	-45%
Ksilt decr 10%	-4%	-4%	-5%
as is	0%	0%	0%
Ksilt incr 10%	8%	8%	9%
Ksilt incr 50%	37%	41%	43%



Appendix A8

Feasibility Study Alternatives

Modeling

Fate and Transport Analysis
Benzene and Chrysene
Source Areas to APOC and APOC to APOE

COC	Degredation Rate - Source to POC	Degredation Rate - POC to POE	Source	Concentration @ Source	Concentration @ POC (mg/L)	Concentration @ POE (mg/L)	MTCA Method B Surface Water Exceedence @POC?	MTCA Method B Surface Water Exceedence @POE?	Feasibility Study Alternative
Benzene	0	0.535	QPNS	Pre excavation	3.54E+00	2.96E-19	Yes	No	AC0/BD1
Benzene	0 / 0.535	0.535	QPNS	Pre excavation	1.78E-08	1.49E-27	No	No	AC0/BD1
Benzene	0	0.535	QPNS	Post excavation	3.22E-01	2.69E-20	Yes	No	AC2/BD1 & AC3/BD1
Benzene	0	0	QPNS	Pre excavation	1.53E+01	6.90E+00	Yes	Yes	No Action
Benzene	0	0.535	NSFS	Pre excavation	1.04E-01	4.77E-25	Yes	No	AC2/BD1
Benzene	0	0.535	NSFS	Post excavation	3.47E-05	1.59E-28	No	No	AC3/BD1
Benzene	0	0.535	SHFS	Pre excavation	4.05E-02	2.27E-26	No	No	AC2/BD1
Benzene	0	0.535	SHFS	Post excavation	2.72E-05	1.53E-29	No	No	AC3/BD1
Benzene	0	0.535	MCNS	Pre excavation	7.07E+00	2.06E-18	Yes	No	AC0/BD1
Benzene	0	0.535	MCNS	Post excavation	6.43E-01	1.88E-19	Yes	No	AC2/BD1
Chrysene	0	0.0549	QPNS	Pre excavation	1.29E-03	7.04E-09	Yes	No	AC0/BD1
Chrysene	0 / 0.0549	0.0549	QPNS	Pre excavation	2.47E-05	1.35E-10	No	No	AC0/BD2
Chrysene	0	0.0549	QPNS	Post excavation	1.07E-04	5.84E-10	Yes	No	AC2/BD1 & AC3/BD1
Chrysene	0	0	QPNS	Pre excavation	5.57E-03	2.51E-03	Yes	Yes	No Action
Chrysene	0	0.0549	NSFS	Pre excavation	4.16E-04	3.48E-11	Yes	No	AC2/BD1
Chrysene	0	0.0549	NSFS	Post excavation	3.47E-05	2.90E-12	Yes	No	AC3/BD1
Chrysene	0	0.0549	SHFS	Pre excavation	3.86E-04	2.16E-11	Yes	No	AC2/BD1
Chrysene	0	0.0549	SHFS	Post excavation	2.72E-05	1.52E-12	No	No	AC3/BD1
Chrysene	0	0.0549	MCNS	Pre excavation	2.57E-03	9.15E-09	Yes	No	AC0/BD1
Chrysene	0	0.0549	MCNS	Post excavation	2.14E-04	7.62E-10	Yes	No	AC2/BD1

Notes:

The pre and post excavation concentrations are selected to represent anticipated concentrations that exist before and after source removal. The concentrations provided have been evaluated and justified in comparison to the existing site concentrations.

Refer to table 5-X for the nearshore and farshore pre and post excavation concentrations.

Fate2 was used to model the contaminant transport from the source areas to the POC and then from the POC to the POE. No degredation was assumed from the source areas to the POC. Biosparging was represented with a degeredation rate equal to 1/10 of the aerobic degredation rate determined in the Lab Treatability Study [RETEC 1997]., applied from the POC to the POE. No degredation was assumed from the POC to the POE for the no action scenario (no biosparging).

The MTCA Method B Surface Water Limit for benzene is 4.3 x10-2 mg/L.
The MTCA Method B Surface Water Limit for chrysene is 2.96 x10-5 mg/L

The Feasibility Study Alternatives are cross referenced to the alternatives presented in the Feasibility Study [RETEC 1997] ie AC0/BD1.

Port Quendall Company
Source Characterization

Source	Width Perpedicular to Groundwater Gradient	Thickness Below Water Table	Distance from Source to POC (Downgradient Edge of Outer Fill/Shoreline)	Distance from POC to POE (Pt of Emergence into Lake Washington)
NSFS - Wall with 2.9 Acre CDF Fill	227	5	261	276
QPNS - Base case scenario - no wall and no fill	264	18	50	150
QPNS - Wall with 2.9 Acre CDF Fill	264	18	301	201
SHFS - Wall with 2.9 Acre CDF Fill	446	7	477	301
MCNS - Wall with 2.9 Acre CDF Fill	122	6	53	181

Notes:
The source dimensions are derived from the information presented in the Feasibility Study.

The distances of the pathlines are calculated based on the dimensions taken from Modpath particle tracking output. The Mopath output is presented in Appendix A3, the pathline length calculations are presented in Appendix A5.

Run	COC	Degredation Rate - Source to POC	Degredation Rate - POC to POE	Source	Concentration @ Critical Source	Concentration @ POC	Concentration @ POE
101	Benzene	0		QPNS	Pre excavation	3.54E+00	
102	Benzene		1/10th Lab	QPNS	Pre excavation	3.54E+00	2.96E-19
103	Benzene	0		QPNS	Post excavation	3.22E-01	
104	Benzene		1/10th Lab	QPNS	Post excavation	3.22E-01	2.69E-20
105	Benzene	0		NSFS	Pre excavation	1.15E+00	
106	Benzene		1/10th Lab	NSFS	Pre excavation	1.15E+00	5.27E-24
107	Benzene	0		NSFS	Post excavation	1.04E-01	
108	Benzene		1/10th Lab	NSFS	Post excavation	1.04E-01	4.77E-25
109	Benzene	0		SHFS	Pre excavation	4.45E-01	
110	Benzene		1/10th Lab	SHFS	Pre excavation	4.45E-01	2.50E-25
111	Benzene	0		SHFS	Post excavation	8.17E-02	
112	Benzene		1/10th Lab	SHFS	Post excavation	8.17E-02	4.58E-26
113	Benzene	0		MCNS	Pre excavation	7.07E+00	
114	Benzene		1/10th Lab	MCNS	Pre excavation	7.07E+00	2.06E-18
115	Benzene	0		MCNS	Post excavation	6.43E-01	
116	Benzene		1/10th Lab	MCNS	Post excavation	6.43E-01	1.88E-19
117	Benzene		0	MCNS	Post excavation	6.43E-01	6.86E-02
118	Benzene	0		QPNS	Pre excavation	1.53E+01	
119	Benzene		0	QPNS	Pre excavation	1.53E+01	6.90E+00
201	Chrysene	0		QPNS	Pre excavation	1.29E-03	
202	Chrysene		1/10th Lab	QPNS	Pre excavation	1.29E-03	7.04E-09
203	Chrysene	0		QPNS	Post excavation	1.07E-04	
204	Chrysene		1/10th Lab	QPNS	Post excavation	1.07E-04	5.84E-10
205	Chrysene	0		NSFS	Pre excavation	4.16E-04	
206	Chrysene		1/10th Lab	NSFS	Pre excavation	4.16E-04	3.48E-11
207	Chrysene	0		NSFS	Post excavation	3.47E-05	
208	Chrysene		1/10th Lab	NSFS	Post excavation	3.47E-05	2.90E-12
209	Chrysene	0		SHFS	Pre excavation	3.86E-04	
210	Chrysene		1/10th Lab	SHFS	Pre excavation	3.86E-04	2.16E-11
211	Chrysene	0		SHFS	Post excavation	2.72E-05	
212	Chrysene		1/10th Lab	SHFS	Post excavation	2.72E-05	1.52E-12
213	Chrysene	0		MCNS	Pre excavation	2.57E-03	
214	Chrysene		1/10th Lab	MCNS	Pre excavation	2.57E-03	9.15E-09
215	Chrysene	0		MCNS	Post excavation	2.14E-04	
216	Chrysene		1/10th Lab	MCNS	Post excavation	2.14E-04	7.62E-10
217	Chrysene		0	MCNS	Post excavation	2.14E-04	2.28E-05
218	Chrysene	0		QPNS	Pre excavation	5.57E-03	
219	Chrysene		0	QPNS	Pre excavation	5.57E-03	2.51E-03

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	16.5
Y - source width perpendicular to groundwater flow [ft]	264
Z - source depth below water table [ft]	18
L - farthest distance to be evaluated from source [ft]	3000

NOTES:
This run simulates benzene from the source at qpns best case scenario.

3) Input Monitoring Point Data:
Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	301
Cgw* - Target Concentration [mg/l]	4.30E-02

MODEL CALIBRATION

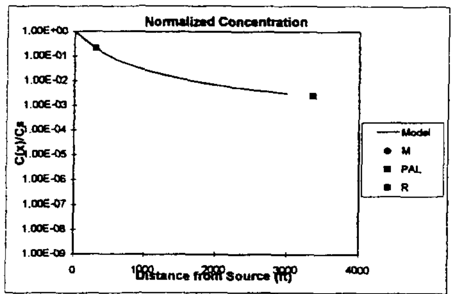
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

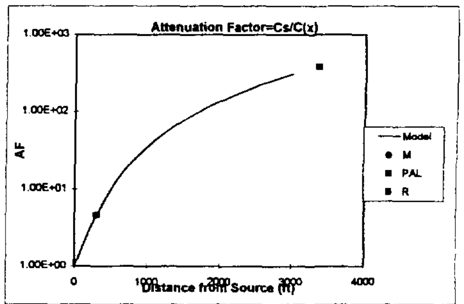
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.84E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.87E-05

PAL

PAL - Plume Attenuation Length [ft]	3354	
PAL/L - Scaled Plume Attenuation Length	1.12	
R - Distance to Nearest Receptor Location [ft]	301	Receptor is w/in Pl

Time to Reach Steady State	(yr)
PAL	39
M1	<1
M2	<1
M3	<1
R	3

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	4.66E+00	
Cr - Concentration at Receptor [mg/l]	3.54E+00	Exceeds Target
Cgw* - Target Concentration [mg/l]	0.043	

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.20	
Cs - Source Concentration [mg/l]	16.50	Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	**Input**		**Min**	**Max**
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.535**	**Min**	0.535	0.535
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	**3.54**
Y - source width perpendicular to groundwater flow [ft]	**264**
Z - source depth below water table [ft]	**18**
L - farthest distance to be evaluated from source [ft]	**3000**

NOTES:

This run simulates benzene from the source at qpns best case scenario.

3) Input Monitoring Point Data:

Monitoring Point

Cm - concentration at monitoring locations [mg/l]

M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	**201**
Cgw* - Target Concentration [mg/l]	**4.30E-02**

MODEL CALIBRATION

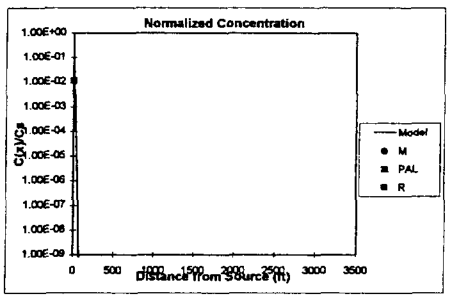
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.5350	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

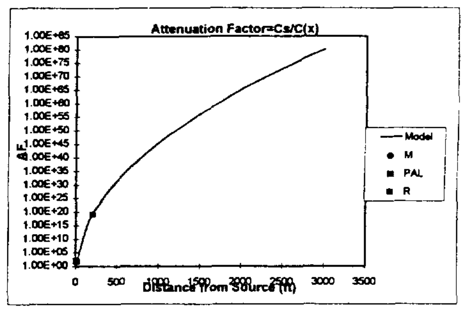
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	8.23E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-7.32E-05

PAL

PAL - Plume Attenuation Length [ft]	6
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	201

Time to Reach Steady State (yr)	
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation	
AFr - Attenuation Factor at Receptor	1.20E+19
Cr - Concentration at Receptor [mg/l]	2.96E-19
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration	
Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	3.54

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	**Input**		**Min**	**Max**
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0**	**Min**	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	**1.5**
Y - source width perpendicular to groundwater flow [ft]	**264**
Z - source depth below water table [ft]	**18**
L - farthest distance to be evaluated from source [ft]	**3000**

NOTES:

This run simulates benzene from the source at qpns best case scenario.

3) Input Monitoring Point Data:

Monitoring Point

Cm - concentration at monitoring locations [mg/l]

M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	**301**
Cgw* - Target Concentration [mg/l]	**4.30E-02**

MODEL CALIBRATION

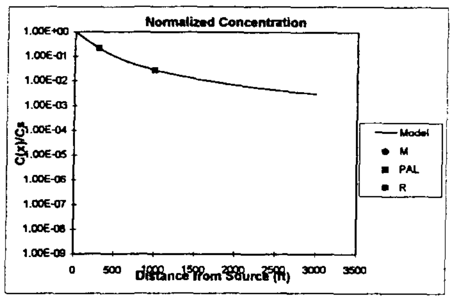
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

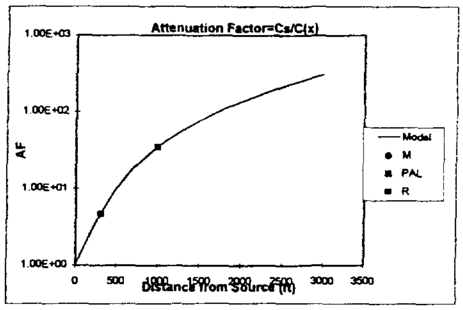
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	3.49E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	3.50E-04

PAL

PAL - Plume Attenuation Length [ft]	990
PAL/L - Scaled Plume Attenuation Length	0.33
R - Distance to Nearest Receptor Location [ft]	301 **Receptor is w/in Pl**

Time to Reach Steady State	(yr)
PAL	11
M1	<1
M2	<1
M3	<1
R	3

7) Receptor Attenuation		
AFr - Attenuation Factor at Receptor	4.66E+00	
Cr - Concentration at Receptor [mg/l]	3.22E-01	**Exceeds Target**
Cgw* - Target Concentration [mg/l]	0.043	

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration		
Cs* - Maximum Source Concentration [mg/l]	0.20	
Cs - Source Concentration [mg/l]	1.50	**Source Reduction Rqrd**

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.535**	**Min**	0.535	0.535
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**3.22E-01**
Y - source width perpendicular to groundwater flow [ft]	**264**
Z - source depth below water table [ft]	**18**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**201**
Cgw* - Target Concentration [mg/l]	**4.30E-02**

MODEL CALIBRATION

5) Run Calibration Macros

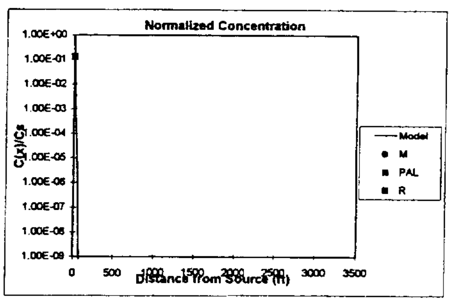
lamda - attenuation rate [1/day] (.001 - .01)	0.5350	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

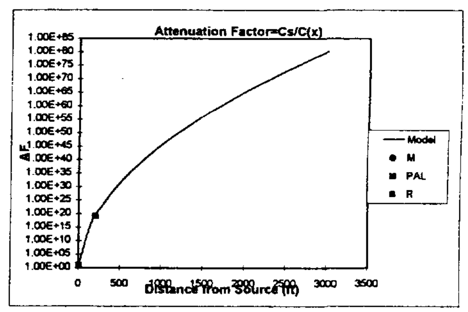
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	7.49E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-2.04E-04

PAL

PAL - Plume Attenuation Length [ft]	2
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	201

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.20E+19
Cr - Concentration at Receptor [mg/l]	2.69E-20
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	0.32

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0**	**Min**	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**1.65E+01**
Y - source width perpendicular to groundwater flow [ft]	**227**
Z - source depth below water table [ft]	**5**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**261**
Cgw* - Target Concentration [mg/l]	**4.30E-02**

MODEL CALIBRATION

5) Run Calibration Macros

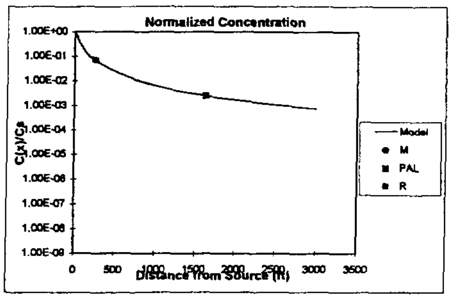
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

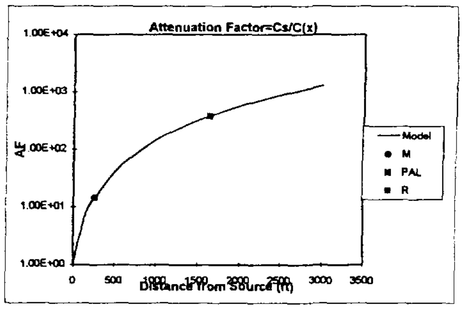
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.84E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.47E-05

PAL

PAL - Plume Attenuation Length [ft]	1633	
PAL/L - Scaled Plume Attenuation Length	0.54	
R - Distance to Nearest Receptor Location [ft]	261	**Receptor is w/in Pl**

Time to Reach Steady State	(yr)
PAL	19
M1	<1
M2	<1
M3	<1
R	3

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.44E+01	
Cr - Concentration at Receptor [mg/l]	1.15E+00	**Exceeds Target**
Cgw* - Target Concentration [mg/l]	0.043	

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.62	
Cs - Source Concentration [mg/l]	16.50	**Source Reduction Rqrd**

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.535	Min	0.535	0.535
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	1.15E+00
Y - source width perpendicular to groundwater flow [ft]	227
Z - source depth below water table [ft]	5
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	276
Cgw* - Target Concentration [mg/l]	4.30E-02

MODEL CALIBRATION

5) Run Calibration Macros

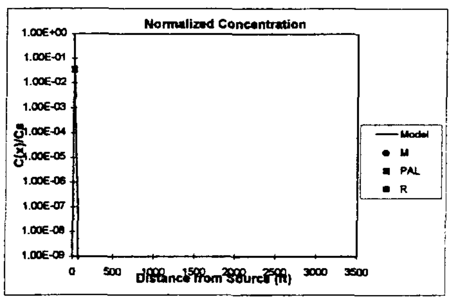
lamda - attenuation rate [1/day] (.001 - .01)	0.5350	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

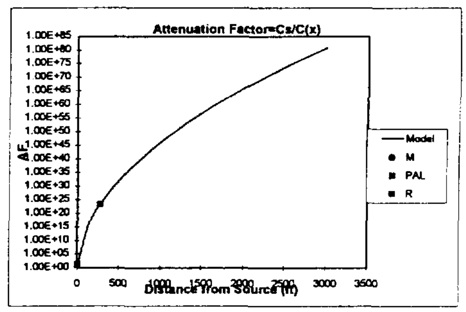
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	2.67E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.66E-05

PAL

PAL - Plume Attenuation Length [ft]	4
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	276

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	2.18E+23
Cr - Concentration at Receptor [mg/l]	5.27E-24
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	1.15

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	1.50E+00
Y - source width perpendicular to groundwater flow [ft]	227
Z - source depth below water table [ft]	5
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	261
Cgw* - Target Concentration [mg/l]	4.30E-02

MODEL CALIBRATION

5) Run Calibration Macros

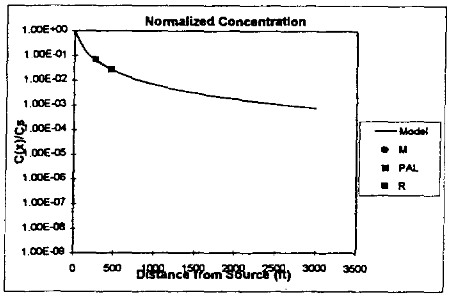
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

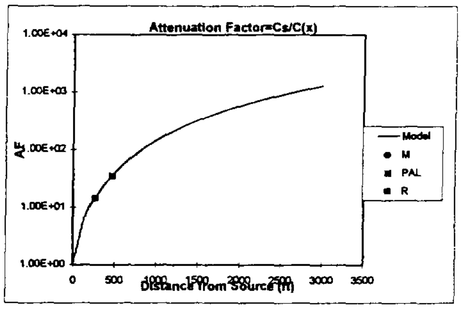
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.49E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	1.93E-04

PAL

PAL - Plume Attenuation Length [ft]	461	
PAL/L - Scaled Plume Attenuation Length	0.15	
R - Distance to Nearest Receptor Location [ft]	261	Receptor is w/in Pl

Time to Reach Steady State	(yr)
PAL	5
M1	<1
M2	<1
M3	<1
R	3

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.44E+01	
Cr - Concentration at Receptor [mg/l]	1.04E-01	Exceeds Target
Cgw* - Target Concentration [mg/l]	0.043	

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.62	
Cs - Source Concentration [mg/l]	1.50	Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.535**	**Min**	0.535	0.535
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**1.04E-01**
Y - source width perpendicular to groundwater flow [ft]	**227**
Z - source depth below water table [ft]	**5**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**276**
Cgw* - Target Concentration [mg/l]	**4.30E-02**

MODEL CALIBRATION

5) Run Calibration Macros

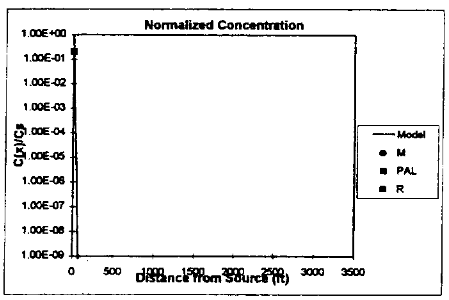
lamda - attenuation rate [1/day] (.001 - .01)	0.5350	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

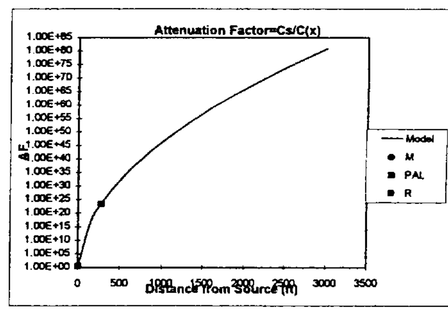
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	2.42E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-9.92E-01

PAL

PAL - Plume Attenuation Length [ft]	2
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	276

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	2.18E+23
Cr - Concentration at Receptor [mg/l]	4.77E-25
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	0.10

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	1.65E+01
Y - source width perpendicular to groundwater flow [ft]	227
Z - source depth below water table [ft]	5
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	477
Cgw* - Target Concentration [mg/l]	4.30E-02

MODEL CALIBRATION

5) Run Calibration Macros

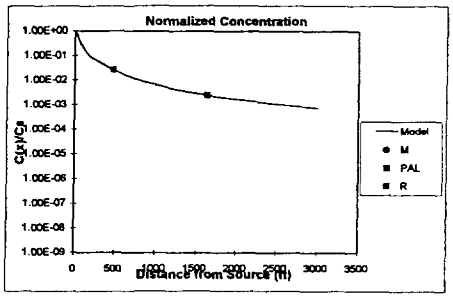
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

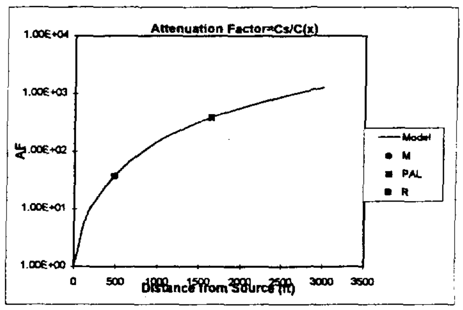
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.84E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-5.54E-06

PAL

PAL - Plume Attenuation Length [ft]	1633	
PAL/L - Scaled Plume Attenuation Length	0.54	
R - Distance to Nearest Receptor Location [ft]	477	Receptor is w/in Pl

Time to Reach Steady State	(yr)
PAL	19
M1	<1
M2	<1
M3	<1
R	6

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	3.71E+01	
Cr - Concentration at Receptor [mg/l]	4.45E-01	Exceeds Target
Cgw* - Target Concentration [mg/l]	0.043	

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	1.59	
Cs - Source Concentration [mg/l]	16.50	Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.535**	**Min**	0.535	0.535
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**4.45E-01**
Y - source width perpendicular to groundwater flow [ft]	**446**
Z - source depth below water table [ft]	**7**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**301**
Cgw* - Target Concentration [mg/l]	**4.30E-02**

MODEL CALIBRATION

5) Run Calibration Macros

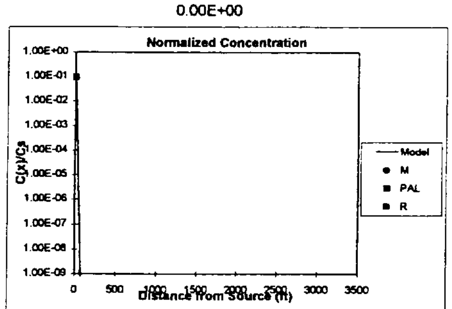
lamda - attenuation rate [1/day] (.001 - .01)	0.5350	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

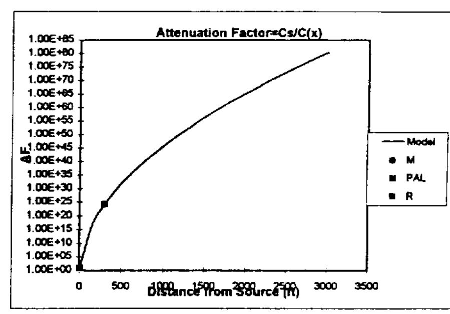
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	1.03E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-3.28E-05

PAL

PAL - Plume Attenuation Length [ft]	3
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	301

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.78E+24
Cr - Concentration at Receptor [mg/l]	2.50E-25
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	0.45

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	1.50E+00
Y - source width perpendicular to groundwater flow [ft]	446
Z - source depth below water table [ft]	7
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	477
Cgw* - Target Concentration [mg/l]	4.30E-02

MODEL CALIBRATION

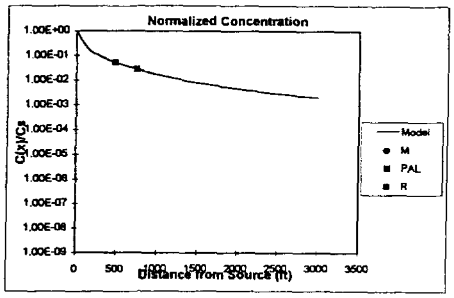
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

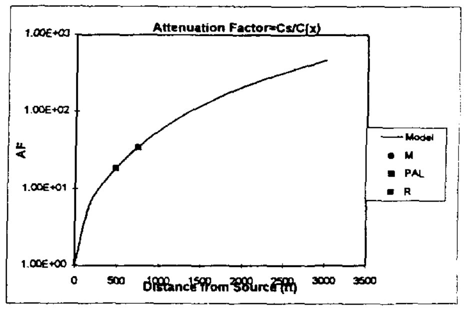
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.49E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-8.38E-05

PAL

PAL - Plume Attenuation Length [ft]	740
PAL/L - Scaled Plume Attenuation Length	0.25
R - Distance to Nearest Receptor Location [ft]	477 Receptor is w/in Pl

	Time to Reach Steady State (yr)
PAL	9
M1	<1
M2	<1
M3	<1
R	6

7) Receptor Attenuation	
AFr - Attenuation Factor at Receptor	1.84E+01
Cr - Concentration at Receptor [mg/l]	8.17E-02 Exceeds Target
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration	
Cs* - Maximum Source Concentration [mg/l]	0.79
Cs - Source Concentration [mg/l]	1.50 Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.535**	**Min**	0.535	0.535
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	**8.17E-02**
Y - source width perpendicular to groundwater flow [ft]	**446**
Z - source depth below water table [ft]	**7**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:
Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	**301**
Cgw* - Target Concentration [mg/l]	**4.30E-02**

MODEL CALIBRATION

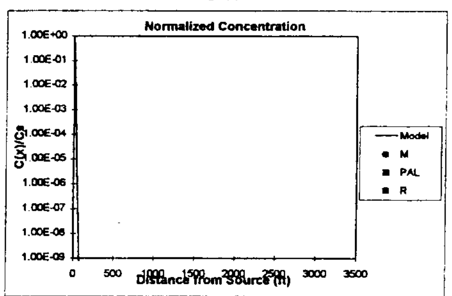
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.5350	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

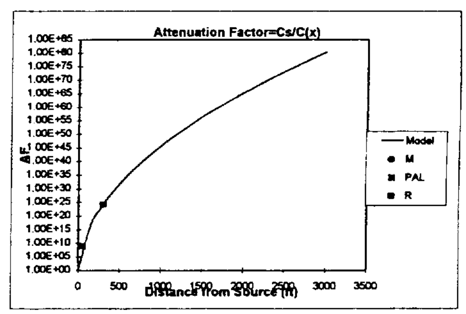
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	1.90E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-6.03E+08

PAL

PAL - Plume Attenuation Length [ft]	54
PAL/L - Scaled Plume Attenuation Length	0.02
R - Distance to Nearest Receptor Location [ft]	301

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation	
AFr - Attenuation Factor at Receptor	1.78E+24
Cr - Concentration at Receptor [mg/l]	4.58E-26
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration	
Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	0.08

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0**	**Min**	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**1.65E+01**
Y - source width perpendicular to groundwater flow [ft]	**122**
Z - source depth below water table [ft]	**6**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**53**
Cgw* - Target Concentration [mg/l]	**4.30E-02**

MODEL CALIBRATION

5) Run Calibration Macros

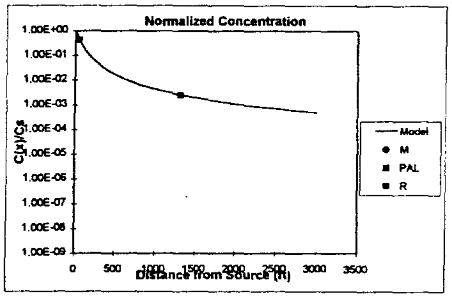
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

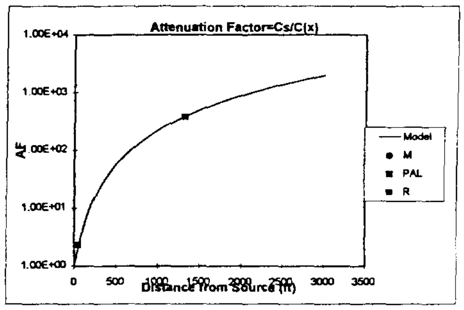
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.84E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-2.12E-05

PAL

PAL - Plume Attenuation Length [ft]	1316	
PAL/L - Scaled Plume Attenuation Length	0.44	
R - Distance to Nearest Receptor Location [ft]	53	**Receptor is w/in Pl**

Time to Reach Steady State	(yr)
PAL	15
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	2.33E+00	
Cr - Concentration at Receptor [mg/l]	7.07E+00	**Exceeds Target**
Cgw* - Target Concentration [mg/l]	0.043	

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.10	
Cs - Source Concentration [mg/l]	16.50	**Source Reduction Rqrd**

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.535**	**Min**	0.535	0.535
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**7.07E+00**
Y - source width perpendicular to groundwater flow [ft]	**122**
Z - source depth below water table [ft]	**6**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**181**
Cgw* - Target Concentration [mg/l]	**4.30E-02**

MODEL CALIBRATION

5) Run Calibration Macros

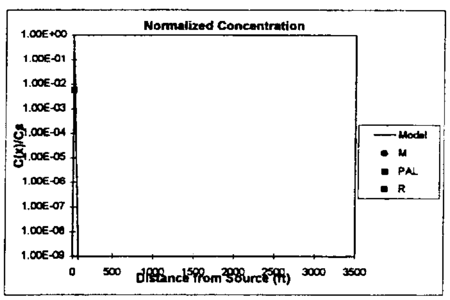
lamda - attenuation rate [1/day] (.001 - .01)	0.5350	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

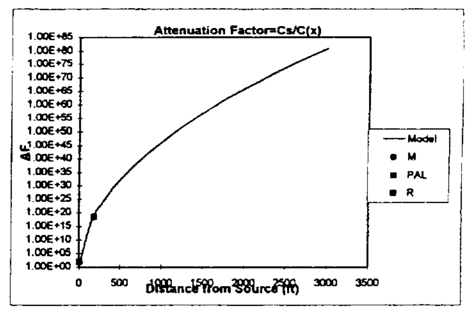
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	1.64E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-5.79E-04

PAL

PAL - Plume Attenuation Length [ft]	7
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	181

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	3.43E+18
Cr - Concentration at Receptor [mg/l]	2.06E-18
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	7.07

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	1.50E+00
Y - source width perpendicular to groundwater flow [ft]	122
Z - source depth below water table [ft]	6
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:

Monitoring Point

Cm - concentration at monitoring locations [mg/l]

M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	53
Cgw* - Target Concentration [mg/l]	4.30E-02

MODEL CALIBRATION

5) Run Calibration Macros

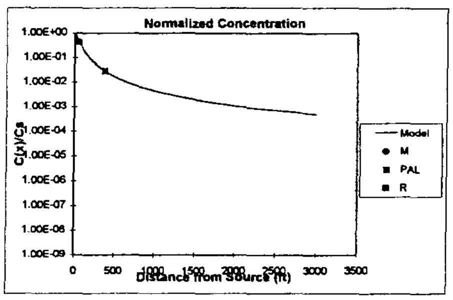
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

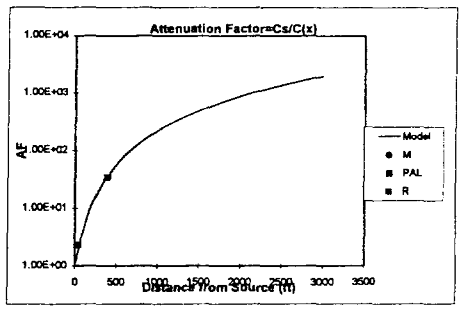
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.49E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	4.97E-04

PAL

PAL - Plume Attenuation Length [ft]	385
PAL/L - Scaled Plume Attenuation Length	0.13
R - Distance to Nearest Receptor Location [ft]	53 Receptor is w/in Pl

Time to Reach Steady State	(yr)
PAL	4
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	2.33E+00	
Cr - Concentration at Receptor [mg/l]	6.43E-01	Exceeds Target
Cgw* - Target Concentration [mg/l]	0.043	

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.10	
Cs - Source Concentration [mg/l]	1.50	Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.535**	**Min**	0.535	0.535
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**6.43E-01**
Y - source width perpendicular to groundwater flow [ft]	**122**
Z - source depth below water table [ft]	**6**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**181**
Cgw* - Target Concentration [mg/l]	**4.30E-02**

MODEL CALIBRATION

5) Run Calibration Macros

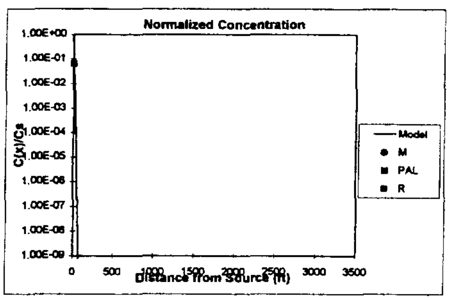
lamda - attenuation rate [1/day] (.001 - .01)	0.5350	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

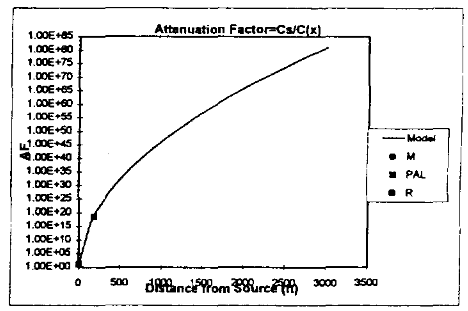
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	1.50E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.30E-04

PAL

PAL - Plume Attenuation Length [ft]	3
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	181

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	3.43E+18
Cr - Concentration at Receptor [mg/l]	1.88E-19
Cgw* - Target Concentration [mg/l]	0.043

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	>S
Cs - Source Concentration [mg/l]	0.64

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0**	**Min**	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**6.43E-01**
Y - source width perpendicular to groundwater flow [ft]	**122**
Z - source depth below water table [ft]	**6**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**181**
Cgw* - Target Concentration [mg/l]	**4.30E-02**

MODEL CALIBRATION

5) Run Calibration Macros

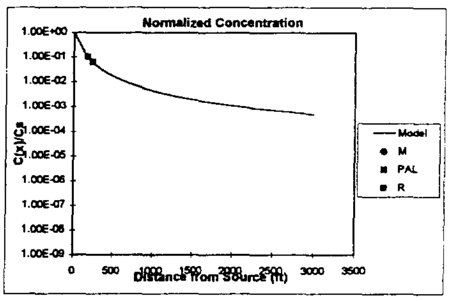
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

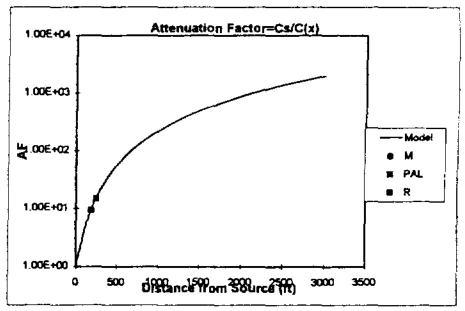
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	1.50E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.25E-05

PAL

PAL - Plume Attenuation Length [ft]	241	
PAL/L - Scaled Plume Attenuation Length	0.08	
R - Distance to Nearest Receptor Location [ft]	181	**Receptor is w/in Pl**

Time to Reach Steady State	(yr)
PAL	3
M1	<1
M2	<1
M3	<1
R	2

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	9.37E+00	
Cr - Concentration at Receptor [mg/l]	6.86E-02	**Exceeds Target**
Cgw* - Target Concentration [mg/l]	0.043	

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.40	
Cs - Source Concentration [mg/l]	0.64	**Source Reduction Rqrd**

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	**Input**		**Min**	**Max**
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	16.5
Y - source width perpendicular to groundwater flow [ft]	264
Z - source depth below water table [ft]	18
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	50
Cgw* - Target Concentration [mg/l]	4.30E-02

MODEL CALIBRATION

5) Run Calibration Macros

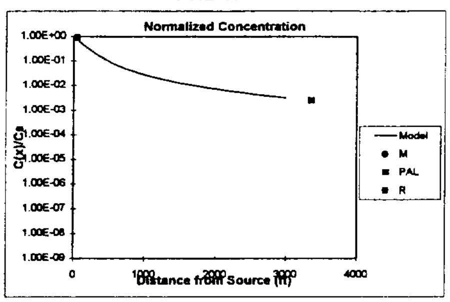
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

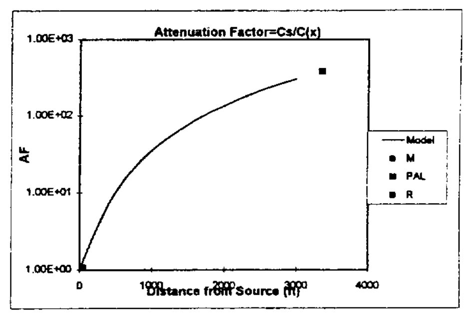
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.84E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.87E-05

PAL

PAL - Plume Attenuation Length (ft)	3354	
PAL/L - Scaled Plume Attenuation Length	1.12	
R - Distance to Nearest Receptor Location [ft]	50	Receptor is w/in Pl

Time to Reach Steady State	(yr)
PAL	39
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.08E+00	
Cr - Concentration at Receptor [mg/l]	1.53E+01	Exceeds Target
Cgw* - Target Concentration [mg/l]	0.043	

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.05	
Cs - Source Concentration [mg/l]	16.50	Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	1.53E+01
Y - source width perpendicular to groundwater flow [ft]	264
Z - source depth below water table [ft]	18
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:
Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	150
Cgw* - Target Concentration [mg/l]	4.30E-02

MODEL CALIBRATION

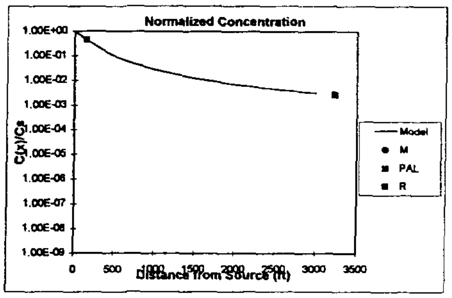
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

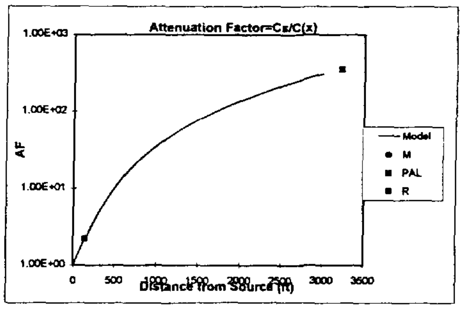
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"		
Cs/Cgw* - attenuation factor at target concentration	3.56E+02	
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	7.31E-04	
PAL - Plume Attenuation Length [ft]	3228	
PAL/L - Scaled Plume Attenuation Length	1.08	
R - Distance to Nearest Receptor Location [ft]	150	Receptor is w/in Pl

PAL

Time to Reach Steady State	(yr)
PAL	37
M1	<1
M2	<1
M3	<1
R	2

7) Receptor Attenuation		
AFr - Attenuation Factor at Receptor	2.22E+00	
Cr - Concentration at Receptor [mg/l]	6.90E+00	Exceeds Target
Cgw* - Target Concentration [mg/l]	0.043	

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration		
Cs* - Maximum Source Concentration [mg/l]	0.10	
Cs - Source Concentration [mg/l]	15.30	Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0**	**Min**	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**0.006**
Y - source width perpendicular to groundwater flow [ft]	**264**
Z - source depth below water table [ft]	**18**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**301**
Cgw* - Target Concentration [mg/l]	**2.96E-05**

MODEL CALIBRATION

5) Run Calibration Macros

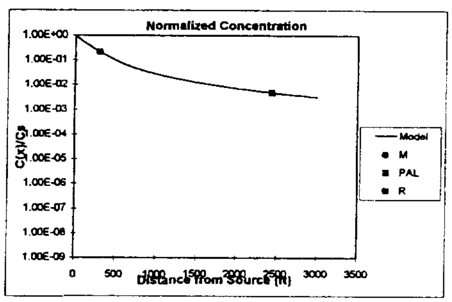
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

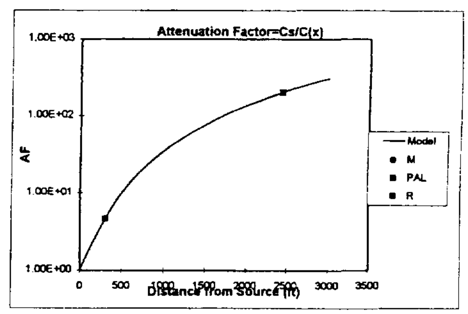
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	2.03E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	1.96E-05

PAL

PAL - Plume Attenuation Length [ft]	2433	
PAL/L - Scaled Plume Attenuation Length	0.81	
R - Distance to Nearest Receptor Location [ft]	301	**Receptor is w/in Pl**

Time to Reach Steady State	(yr)
PAL	28
M1	<1
M2	<1
M3	<1
R	3

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	4.66E+00	
Cr - Concentration at Receptor [mg/l]	1.29E-03	**Exceeds Target**
Cgw* - Target Concentration [mg/l]	0.0000296	

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.00	
Cs - Source Concentration [mg/l]	0.01	**Source Reduction Rqrd**

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.0549	Min	0.0549	0.0549
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	1.29E-03
Y - source width perpendicular to groundwater flow [ft]	264
Z - source depth below water table [ft]	18
L - farthest distance to be evaluated from source [ft]	3000

NOTES:

This run simulates benzene from the source at qpns best case scenario.

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	201
Cgw* - Target Concentration [mg/l]	2.96E-05

MODEL CALIBRATION

5) Run Calibration Macros

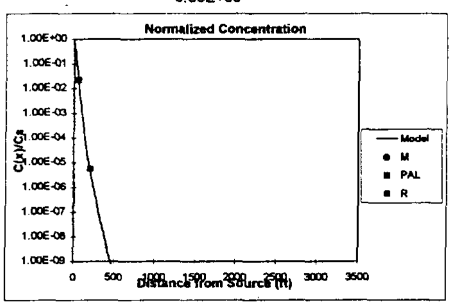
lamda - attenuation rate [1/day] (.001 - .01)	0.0549	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

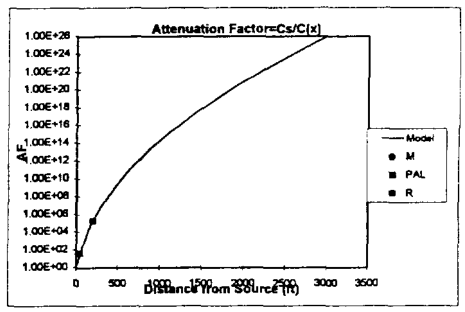
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	4.36E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	1.60E-05

PAL

PAL - Plume Attenuation Length [ft]	44
PAL/L - Scaled Plume Attenuation Length	0.01
R - Distance to Nearest Receptor Location [ft]	201

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.83E+05
Cr - Concentration at Receptor [mg/l]	7.04E-09
Cgw* - Target Concentration [mg/l]	0.0000296

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	5.42
Cs - Source Concentration [mg/l]	0.00

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0**	**Min**	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**0.0005**
Y - source width perpendicular to groundwater flow [ft]	**264**
Z - source depth below water table [ft]	**18**
L - farthest distance to be evaluated from source [ft]	**3000**

NOTES:
This run simulates benzene from the source at qpns best case scenario.

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**301**
Cgw* - Target Concentration [mg/l]	**2.96E-05**

MODEL CALIBRATION

5) Run Calibration Macros

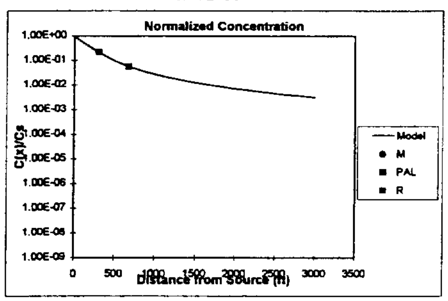
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

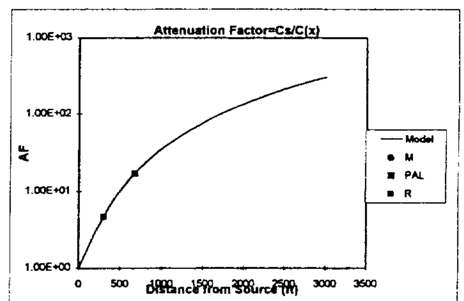
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	1.69E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-3.14E-04

PAL

PAL - Plume Attenuation Length [ft]	672	
PAL/L - Scaled Plume Attenuation Length	0.22	
R - Distance to Nearest Receptor Location [ft]	301	**Receptor is w/in Pl**

Time to Reach Steady State	(yr)
PAL	8
M1	<1
M2	<1
M3	<1
R	3

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	4.66E+00	
Cr - Concentration at Receptor [mg/l]	1.07E-04	**Exceeds Target**
Cgw* - Target Concentration [mg/l]	0.0000296	

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.00	
Cs - Source Concentration [mg/l]	0.00	**Source Reduction Rqrd**

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.0549	Min	0.0549	0.0549
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	1.07E-04
Y - source width perpendicular to groundwater flow [ft]	264
Z - source depth below water table [ft]	18
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:

Monitoring Point

Cm - concentration at monitoring locations [mg/l]

M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	201
Cgw* - Target Concentration [mg/l]	2.96E-05

MODEL CALIBRATION

5) Run Calibration Macros

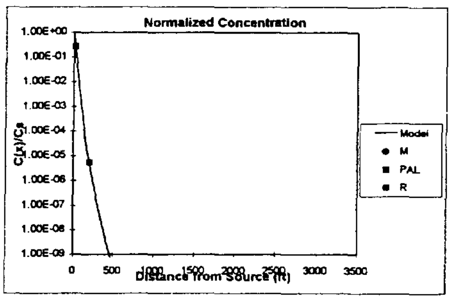
lamda - attenuation rate [1/day] (.001 - .01)	0.0549	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

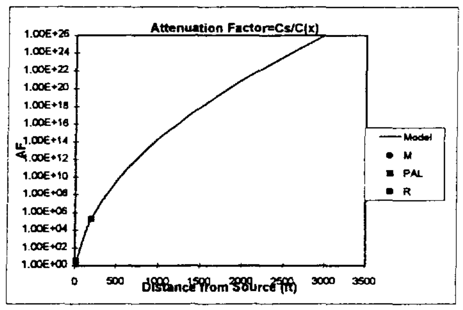
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	3.61E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	8.16E-04

PAL

PAL - Plume Attenuation Length [ft]	13
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	201

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.83E+05
Cr - Concentration at Receptor [mg/l]	5.84E-10
Cgw* - Target Concentration [mg/l]	0.0000296

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	5.42
Cs - Source Concentration [mg/l]	0.00

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0**	**Min**	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**6.00E-03**
Y - source width perpendicular to groundwater flow [ft]	**227**
Z - source depth below water table [ft]	**5**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**261**
Cgw* - Target Concentration [mg/l]	**2.96E-05**

MODEL CALIBRATION

5) Run Calibration Macros

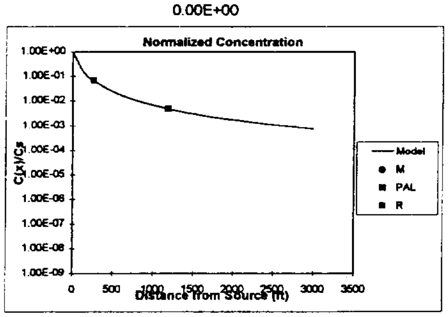
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

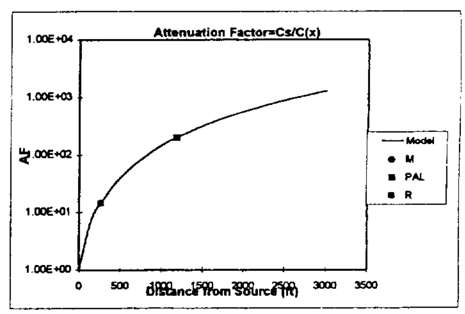
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	2.03E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.06E-04

PAL

PAL - Plume Attenuation Length [ft]	1180	
PAL/L - Scaled Plume Attenuation Length	0.39	
R - Distance to Nearest Receptor Location [ft]	261	**Receptor is w/in Pl**

Time to Reach Steady State	(yr)
PAL	14
M1	<1
M2	<1
M3	<1
R	3

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.44E+01	
Cr - Concentration at Receptor [mg/l]	4.16E-04	**Exceeds Target**
Cgw* - Target Concentration [mg/l]	0.0000296	

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.00	
Cs - Source Concentration [mg/l]	0.01	**Source Reduction Rqrd**

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.0549**	**Min**	0.0549	0.0549
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	**4.16E-04**
Y - source width perpendicular to groundwater flow [ft]	**227**
Z - source depth below water table [ft]	**5**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:
Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	**276**
Cgw* - Target Concentration [mg/l]	**2.96E-05**

MODEL CALIBRATION

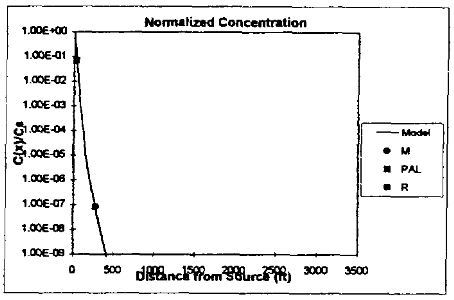
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0549	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

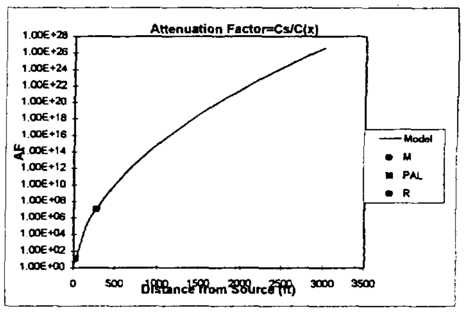
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	1.41E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.88E-04

PAL

PAL - Plume Attenuation Length [ft]	24
PAL/L - Scaled Plume Attenuation Length	0.01
R - Distance to Nearest Receptor Location [ft]	276

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation	
AFr - Attenuation Factor at Receptor	1.20E+07
Cr - Concentration at Receptor [mg/l]	3.48E-11
Cgw* - Target Concentration [mg/l]	0.0000296

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration	
Cs* - Maximum Source Concentration [mg/l]	353.93
Cs - Source Concentration [mg/l]	0.00

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	5.00E-04
Y - source width perpendicular to groundwater flow [ft]	227
Z - source depth below water table [ft]	5
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	261
Cgw* - Target Concentration [mg/l]	2.96E-05

MODEL CALIBRATION

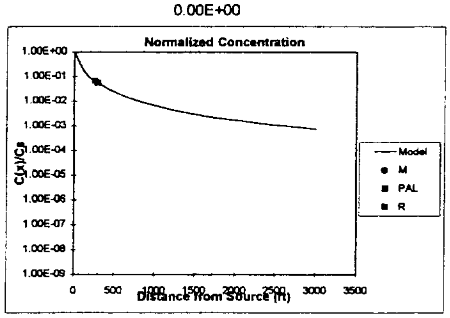
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

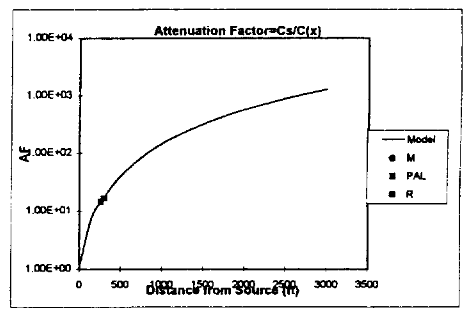
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	1.69E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-8.13E-04

PAL

PAL - Plume Attenuation Length [ft]	293	
PAL/L - Scaled Plume Attenuation Length	0.10	
R - Distance to Nearest Receptor Location [ft]	261	Receptor is w/in Pl

Time to Reach Steady State	(yr)
PAL	3
M1	<1
M2	<1
M3	<1
R	3

7) Receptor Attenuation		
AFr - Attenuation Factor at Receptor	1.44E+01	
Cr - Concentration at Receptor [mg/l]	3.47E-05	Exceeds Target
Cgw* - Target Concentration [mg/l]	0.0000296	

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration		
Cs* - Maximum Source Concentration [mg/l]	0.00	
Cs - Source Concentration [mg/l]	0.00	Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.0549**	**Min**	0.0549	0.0549
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**3.47E-05**
Y - source width perpendicular to groundwater flow [ft]	**227**
Z - source depth below water table [ft]	**5**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**276**
Cgw* - Target Concentration [mg/l]	**2.96E-05**

MODEL CALIBRATION

5) Run Calibration Macros

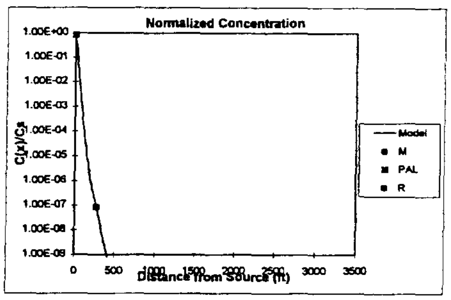
lamda - attenuation rate [1/day] (.001 - .01)	0.0549	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

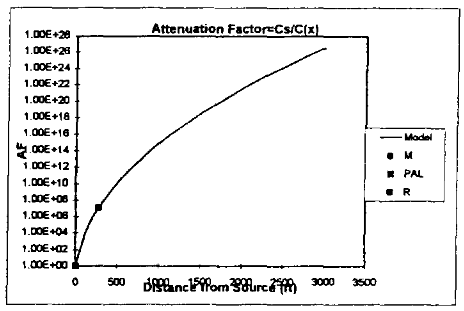
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	1.17E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-4.09E-05

PAL

PAL - Plume Attenuation Length [ft]	1
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	276

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.20E+07
Cr - Concentration at Receptor [mg/l]	2.90E-12
Cgw* - Target Concentration [mg/l]	0.0000296

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	353.93
Cs - Source Concentration [mg/l]	0.00

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	6.00E-03
Y - source width perpendicular to groundwater flow [ft]	227
Z - source depth below water table [ft]	5
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:
Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	276
Cgw* - Target Concentration [mg/l]	2.96E-05

MODEL CALIBRATION

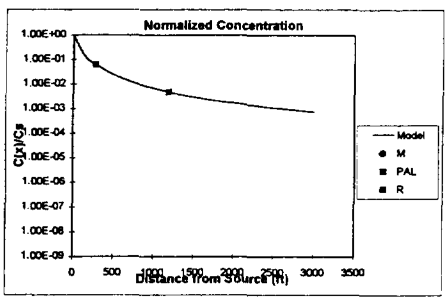
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

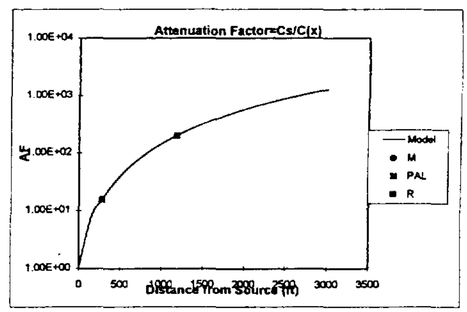
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	2.03E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.50E-04

PAL

PAL - Plume Attenuation Length [ft]	1180	
PAL/L - Scaled Plume Attenuation Length	0.39	
R - Distance to Nearest Receptor Location [ft]	276	Receptor is w/in Pl

Time to Reach Steady State	(yr)
PAL	14
M1	<1
M2	<1
M3	<1
R	3

7) Receptor Attenuation		
AFr - Attenuation Factor at Receptor	1.56E+01	
Cr - Concentration at Receptor [mg/l]	3.86E-04	Exceeds Target
Cgw* - Target Concentration [mg/l]	0.0000296	

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration		
Cs* - Maximum Source Concentration [mg/l]	0.00	
Cs - Source Concentration [mg/l]	0.01	Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	**Input**		**Min**	**Max**
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0.0549**	**Min**	0.0549	0.0549
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**3.86E-04**
Y - source width perpendicular to groundwater flow [ft]	**446**
Z - source depth below water table [ft]	**7**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**301**
Cgw* - Target Concentration [mg/l]	**2.96E-05**

MODEL CALIBRATION

5) Run Calibration Macros

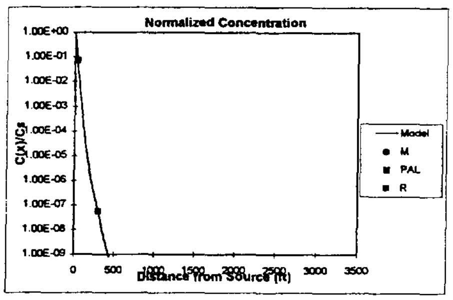
lamda - attenuation rate [1/day] (.001 - .01)	0.0549	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

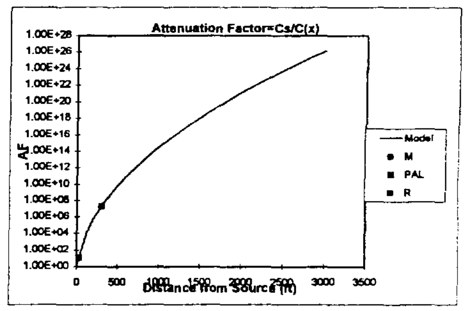
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	1.30E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-3.34E-04

PAL

PAL - Plume Attenuation Length [ft]	26
PAL/L - Scaled Plume Attenuation Length	0.01
R - Distance to Nearest Receptor Location [ft]	301

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.79E+07
Cr - Concentration at Receptor [mg/l]	2.16E-11
Cgw* - Target Concentration [mg/l]	0.0000296

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	529.40
Cs - Source Concentration [mg/l]	0.00

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	5.00E-04
Y - source width perpendicular to groundwater flow [ft]	446
Z - source depth below water table [ft]	7
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:
Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	477
Cgw* - Target Concentration [mg/l]	2.96E-05

MODEL CALIBRATION

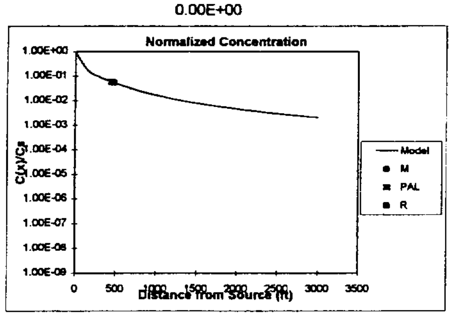
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

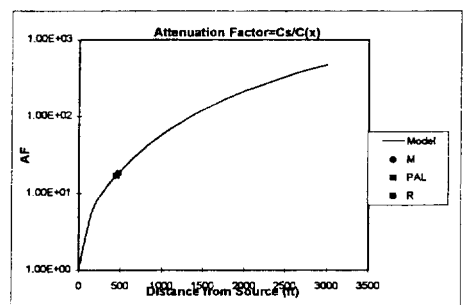
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"	
Cs/Cgw* - attenuation factor at target concentration	1.69E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.86E-05

PAL

PAL - Plume Attenuation Length [ft]	447
PAL/L - Scaled Plume Attenuation Length	0.15
R - Distance to Nearest Receptor Location [ft]	477

Time to Reach Steady State	(yr)
PAL	5
M1	<1
M2	<1
M3	<1
R	6

7) Receptor Attenuation	
AFr - Attenuation Factor at Receptor	1.84E+01
Cr - Concentration at Receptor [mg/l]	2.72E-05
Cgw* - Target Concentration [mg/l]	0.0000296

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration	
Cs* - Maximum Source Concentration [mg/l]	0.00
Cs - Source Concentration [mg/l]	0.00

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.0549	Min	0.0549	0.0549
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	2.72E-05
Y - source width perpendicular to groundwater flow [ft]	446
Z - source depth below water table [ft]	7
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	301
Cgw* - Target Concentration [mg/l]	2.96E-05

MODEL CALIBRATION

5) Run Calibration Macros

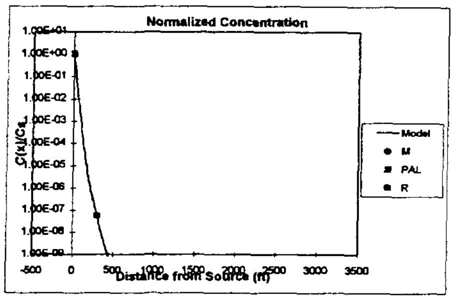
lamda - attenuation rate [1/day] (.001 - .01)	0.0549	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

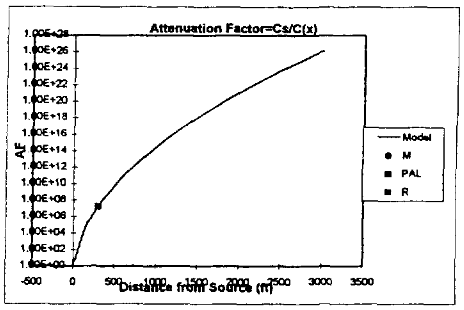
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	9.19E-01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-2.28E-04

PAL

PAL - Plume Attenuation Length [ft]	-1
PAL/L - Scaled Plume Attenuation Length	0.00
R - Distance to Nearest Receptor Location [ft]	301

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	1.79E+07
Cr - Concentration at Receptor [mg/l]	1.52E-12
Cgw* - Target Concentration [mg/l]	0.0000296

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	529.40
Cs - Source Concentration [mg/l]	0.00

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	**Input**		**Min**	**Max**
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0**	**Min**	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	**6.00E-03**
Y - source width perpendicular to groundwater flow [ft]	**122**
Z - source depth below water table [ft]	**6**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	**53**
Cgw* - Target Concentration [mg/l]	**2.96E-05**

MODEL CALIBRATION

5) Run Calibration Macros

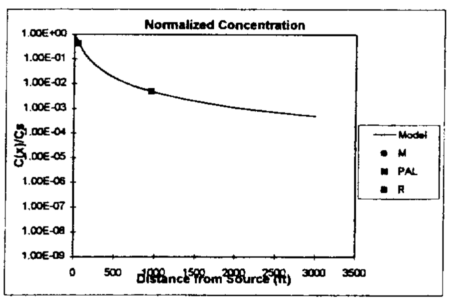
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	**Min**	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

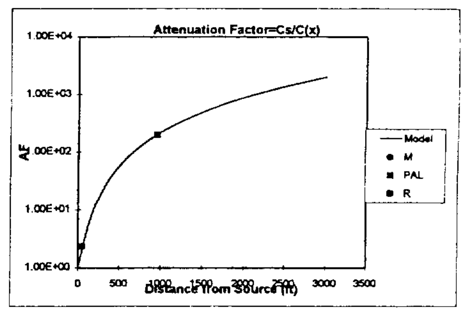
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	2.03E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.01E-04

PAL

PAL - Plume Attenuation Length [ft]	954	
PAL/L - Scaled Plume Attenuation Length	0.32	
R - Distance to Nearest Receptor Location [ft]	53	**Receptor is w/in Pl**

Time to Reach Steady State	(yr)
PAL	11
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	2.33E+00	
Cr - Concentration at Receptor [mg/l]	2.57E-03	**Exceeds Target**
Cgw* - Target Concentration [mg/l]	0.0000296	

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	0.00	
Cs - Source Concentration [mg/l]	0.01	**Source Reduction Rqrd**

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.0549	Min	0.0549	0.0549
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	2.57E-03
Y - source width perpendicular to groundwater flow [ft]	122
Z - source depth below water table [ft]	6
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	181
Cgw* - Target Concentration [mg/l]	2.96E-05

MODEL CALIBRATION

5) Run Calibration Macros

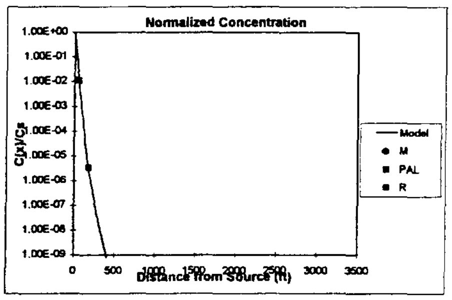
lamda - attenuation rate [1/day] (.001 - .01)	0.0549	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

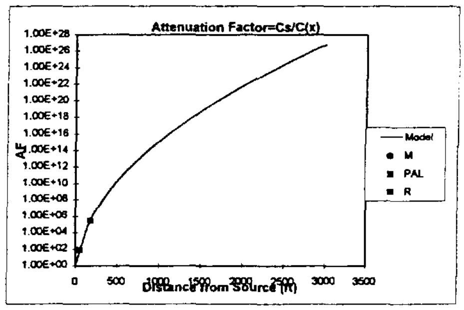
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	8.68E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-2.17E-04

PAL

PAL - Plume Attenuation Length [ft]	45
PAL/L - Scaled Plume Attenuation Length	0.01
R - Distance to Nearest Receptor Location [ft]	181

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	2.81E+05
Cr - Concentration at Receptor [mg/l]	9.15E-09
Cgw* - Target Concentration [mg/l]	0.0000296

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	8.31
Cs - Source Concentration [mg/l]	0.00

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0**	**Min**	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	**5.00E-04**
Y - source width perpendicular to groundwater flow [ft]	**122**
Z - source depth below water table [ft]	**6**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:
Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	**53**
Cgw* - Target Concentration [mg/l]	**2.96E-05**

MODEL CALIBRATION

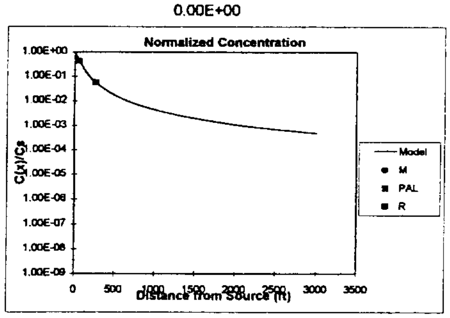
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

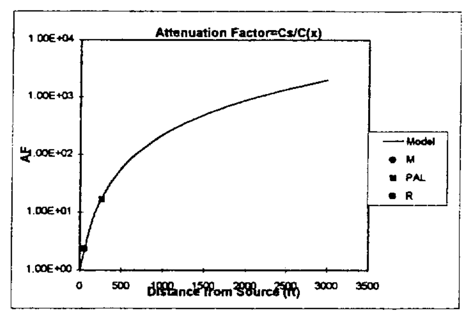
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	1.69E+01
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-3.57E-04

PAL

PAL - Plume Attenuation Length [ft]	259	
PAL/L - Scaled Plume Attenuation Length	0.09	
R - Distance to Nearest Receptor Location [ft]	53	**Receptor is w/in Pl**

Time to Reach Steady State	(yr)
PAL	3
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation		
AFr - Attenuation Factor at Receptor	2.33E+00	
Cr - Concentration at Receptor [mg/l]	2.14E-04	**Exceeds Target**
Cgw* - Target Concentration [mg/l]	0.0000296	

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration		
Cs* - Maximum Source Concentration [mg/l]	0.00	
Cs - Source Concentration [mg/l]	0.00	**Source Reduction Rqrd**

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:

	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0.0549	Min	0.0549	0.0549
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:

Cs - Source Concentration [mg/l]	2.14E-04
Y - source width perpendicular to groundwater flow [ft]	122
Z - source depth below water table [ft]	6
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:

Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:

R - Distance to Nearest Receptor Location [ft]	181
Cgw* - Target Concentration [mg/l]	2.96E-05

MODEL CALIBRATION

5) Run Calibration Macros

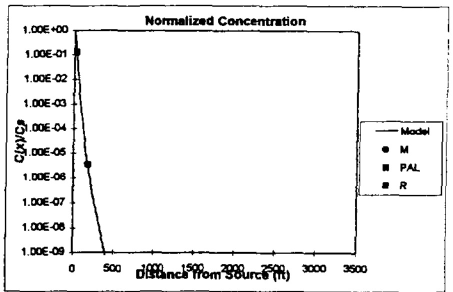
lamda - attenuation rate [1/day] (.001 - .01)	0.0549	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

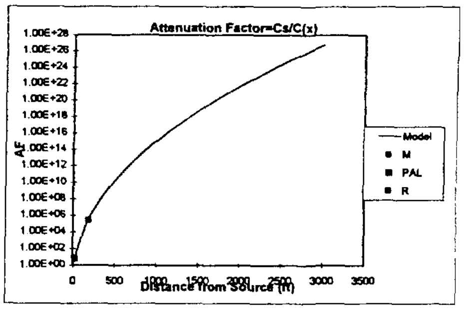
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	7.23E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	1.34E-05

PAL

PAL - Plume Attenuation Length [ft]	19
PAL/L - Scaled Plume Attenuation Length	0.01
R - Distance to Nearest Receptor Location [ft]	181

Time to Reach Steady State	(yr)
PAL	<1
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation

AFr - Attenuation Factor at Receptor	2.81E+05
Cr - Concentration at Receptor [mg/l]	7.62E-10
Cgw* - Target Concentration [mg/l]	0.0000296

8) Input Contaminant Data

S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration

Cs* - Maximum Source Concentration [mg/l]	8.31
Cs - Source Concentration [mg/l]	0.00

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0**	**Min**	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	**2.14E-04**
Y - source width perpendicular to groundwater flow [ft]	**122**
Z - source depth below water table [ft]	**6**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:
Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	**181**
Cgw* - Target Concentration [mg/l]	**2.96E-05**

MODEL CALIBRATION

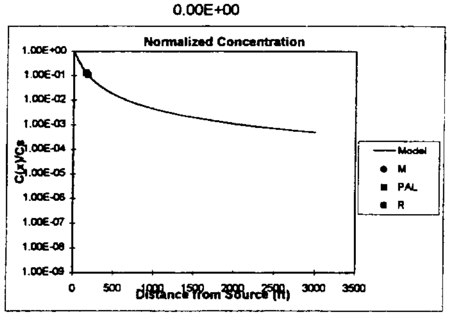
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

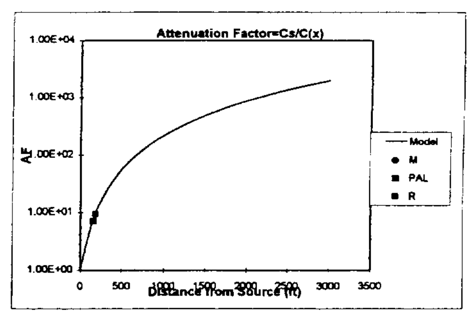
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	7.23E+00
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	1.47E-05

PAL

PAL - Plume Attenuation Length [ft]	152
PAL/L - Scaled Plume Attenuation Length	0.05
R - Distance to Nearest Receptor Location [ft]	181

Time to Reach Steady State	(yr)
PAL	2
M1	<1
M2	<1
M3	<1
R	2

7) Receptor Attenuation	
AFr - Attenuation Factor at Receptor	9.37E+00
Cr - Concentration at Receptor [mg/l]	2.28E-05
Cgw* - Target Concentration [mg/l]	0.0000296

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration	
Cs* - Maximum Source Concentration [mg/l]	0.00
Cs - Source Concentration [mg/l]	0.00

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	Input		Min	Max
n - Porosity [ft^3/ft^3]	0.25		0.1	0.6
K - Hydraulic Conductivity [ft/day]	17.2		0.01	100
i - Groundwater Gradient [ft/ft]	0.0069		0.0001	0.01
lamda - attenuation rate [1/day]	0	Min	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	0.1		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	0.33		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	0.05		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	6.00E-03
Y - source width perpendicular to groundwater flow [ft]	264
Z - source depth below water table [ft]	18
L - farthest distance to be evaluated from source [ft]	3000

3) Input Monitoring Point Data:

Monitoring Point

Cm - concentration at monitoring locations [mg/l]

M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	50
Cgw* - Target Concentration [mg/l]	2.96E-05

MODEL CALIBRATION

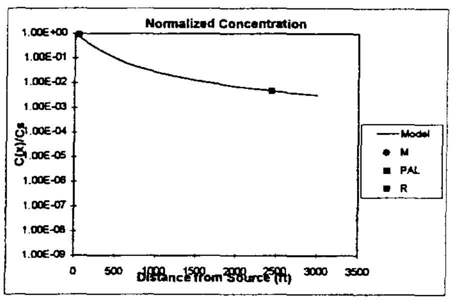
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

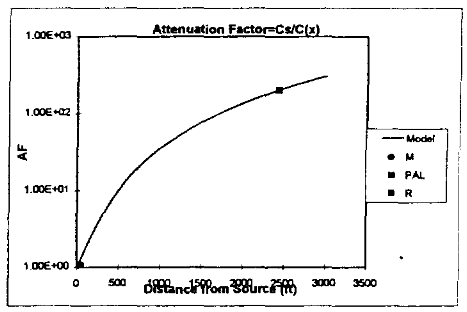
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	2.03E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	1.41E-05

PAL

PAL - Plume Attenuation Length [ft]	2433	
PAL/L - Scaled Plume Attenuation Length	0.81	
R - Distance to Nearest Receptor Location [ft]	50	Receptor is w/in Pl

Time to Reach Steady State	(yr)
PAL	28
M1	<1
M2	<1
M3	<1
R	<1

7) Receptor Attenuation		
AFr - Attenuation Factor at Receptor	1.08E+00	
Cr - Concentration at Receptor [mg/l]	5.57E-03	Exceeds Target
Cgw* - Target Concentration [mg/l]	0.0000296	

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	1750
R - Retardation Factor	2

9) Target Source Concetration		
Cs* - Maximum Source Concentration [mg/l]	0.00	
Cs - Source Concentration [mg/l]	0.01	Source Reduction Rqrd

Plume Attenuation Model: FATE2

MODEL PARAMETER INPUT

1) Input Flow Model Parameters:	**Input**		**Min**	**Max**
n - Porosity [ft^3/ft^3]	**0.25**		0.1	0.6
K - Hydraulic Conductivity [ft/day]	**17.2**		0.01	100
i - Groundwater Gradient [ft/ft]	**0.0069**		0.0001	0.01
lamda - attenuation rate [1/day]	**0**	**Min**	0	0
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x]	**0.1**		0.05	0.2
My - multiplier for transverse dispersivity [alpha-y = My*alpha-	**0.33**		0.1	0.3333
Mz - multiplier for vertical dispersivity [alpha-z = Mz*alpha-x]	**0.05**		0.0125	0.1

2) Input Source Data:	
Cs - Source Concentration [mg/l]	**5.57E-03**
Y - source width perpendicular to groundwater flow [ft]	**264**
Z - source depth below water table [ft]	**18**
L - farthest distance to be evaluated from source [ft]	**3000**

3) Input Monitoring Point Data:
Monitoring Point
Cm - concentration at monitoring locations [mg/l]
M - Distance to Monitoring Locations [ft]

4) Input Receptor Data:	
R - Distance to Nearest Receptor Location [ft]	**150**
Cgw* - Target Concentration [mg/l]	**2.96E-05**

MODEL CALIBRATION

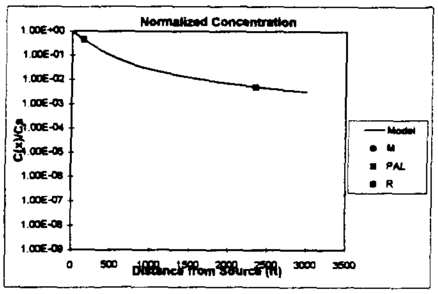
5) Run Calibration Macros			
lamda - attenuation rate [1/day] (.001 - .01)	0.0000	Min	(from cell B8)
Mx - multiplier for longitudinal dispersivity [alpha-x = Mx*x] (0.	0.1000		(from cell B9)
AFm - attenuation factor at location m	#DIV/0!	#DIV/0!	#DIV/0!
Xm - Normalized concentration at location m	0.00E+00	#######	0.00E+00
Xm* - modeled normalized concentration at location m	0.00E+00	#######	0.00E+00
(1-Xm*/Xm)^2	0.00E+00	#######	0.00E+00
Sum of Squares (1-Xm*/Xm)^2	0.00E+00		

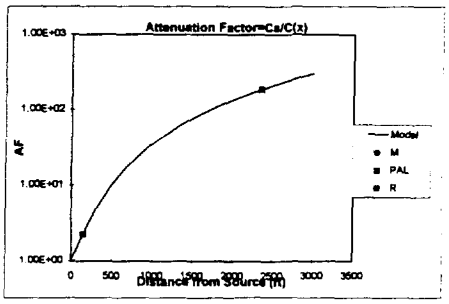
INITIAL - Initialize Inputs

CAL - Calibrate Lamda

CAL2 - Calibrate Mx

CAL3 - Calibrate Lamda & Mx





MODEL OUTPUT

6) Run Plume Attenuation Length Macro "PAL"

Cs/Cgw* - attenuation factor at target concentration	1.88E+02
(Cs/Cgw* - AFpal)/(Cs/Cgw*)	-1.40E-05

PAL

PAL - Plume Attenuation Length [ft]	2344	
PAL/L - Scaled Plume Attenuation Length	0.78	
R - Distance to Nearest Receptor Location [ft]	150	**Receptor is w/in Pl**

Time to Reach Steady State	(yr)
PAL	27
M1	<1
M2	<1
M3	<1
R	2

7) Receptor Attenuation		
AFr - Attenuation Factor at Receptor	2.22E+00	
Cr - Concentration at Receptor [mg/l]	2.51E-03	**Exceeds Target**
Cgw* - Target Concentration [mg/l]	0.0000296	

8) Input Contaminant Data	
S - Solubility Limit of Contaminant (mg/l)	**1750**
R - Retardation Factor	**2**

9) Target Source Concetration		
Cs* - Maximum Source Concentration [mg/l]	0.00	
Cs - Source Concentration [mg/l]	0.01	**Source Reduction Rqrd**

Appendix A9

Preliminary Groundwater Memo,

Ecology Comments and Responses

RETEC

MEMORANDUM

TO:	Port Quendall Distribution	DATE:	April 4, 1997
FROM:	Stephen Codrington - RETEC Mike Riley - S.S. Papadopulos	RE:	Site Groundwater Model

1 Introduction

The Port Quendall Development project is a proposed development of several former industrial properties located on the shore of Lake Washington at the end of the May Creek drainage. The locations of the properties are shown in Figure 1-1 and include the Baxter North and South Parcels, Quendall Terminals property, and Pan Abode property.

This memorandum discusses the groundwater modeling proposed as part of a feasibility study for the project area and is intended as an interim status report on the modeling effort for the Department of Ecology. The document is intended for discussion purposes only.

1.1 Modeling Objectives

The three dimensional groundwater model being developed will be used to simulate various remedial alternatives and their effects on groundwater flow and contaminant transport. Remedial alternatives may include site capping, a containment wall, *in situ* treatment systems, and groundwater extraction and treatment.

Site data are available and of a sufficient quantity and quality to justify a three dimensional model. The site geological model is based on extensive site investigations by RETEC, Hart Crowser (1996), and Woodward-Clyde Consultants (1990). The site geological interpretation has been extrapolated from site boundaries to model boundaries using additional sources of information including Department of Transportation (DOT) borings, local well logs, and published regional geological interpretations. Water level data have been compiled and analyzed to characterize the seasonal variations and provide coverage for the entire model area. The source areas to be used in the fate and transport evaluation are outlined in the Uplands Constituents Memorandum (RETEC, 1997).

Hart Crowser (1996) has completed a draft remedial investigation of the Quendall Terminals property including a simple, two-dimensional flowpath model. The objective of this work was to simulate the groundwater system, estimate the depth of vertical flow components, and estimate the distance from the shore that the lake environment might be affected by contaminated groundwater discharge.

A remedial investigation of the Baxter property was conducted by Woodward-Clyde Consultants (1990). This study did not include a groundwater modeling effort although some hydraulic testing was conducted.

A more complex modeling approach is now proposed as part of the Port Quendall Development Feasibility Study. The more complex approach is warranted in order to predict the effect of the remedial alternatives on groundwater flow patterns and contaminant transport. Specific issues to be investigated include: the feasibility of installing an *in situ* treatment system, depth and extent of a proposed containment wall, a possible pump-and-treat system, and chemical fate and transport under pre- and post-remediation conditions.

2 Geologic Setting

The geology at the project area consists of alluvial material deposited by May Creek, Lake Washington sediments, and fill material deposited as part of previous site development. The fill material is a complex mixture of sand, silt, gravel, and wood debris from previous industrial activities in the project area. The fill material is largely unsaturated and consequently is not significant for groundwater modeling considerations.

Below the fill material is a complex, interbedded layer of silt, sand, and peat that is probably a mixture of May Creek sediment deposits and Lake Washington sediment deposits that predate construction of the Lake Washington Ship Canal, when the water level in the lake was higher. This layer shows a high degree of heterogeneity both vertically and horizontally due to changes in the May Creek channel alignment over time. This layer is saturated over most of its depth which extends from approximately 5 to 30 feet below ground surface (bgs).

The silt-peat layer grades into a deeper layer of dense sand and gravel that may be older May Creek alluvium or part of a deeper regional aquifer in Vashon outwash deposits. Over most of this aquifer, the water levels are similar to the water levels in the silt-peat layer. However, recent borings by Shannon & Wilson found artesian conditions at a depth of greater than 100 feet bgs. Although no definitive confining unit was encountered, there is obviously an impediment to vertical flow at this depth. Based on these deep borings, it is inferred that these borings encountered the regional Vashon outwash aquifer and that the dense sand and gravel layer is part of the May Creek alluvial fan deposit. This is consistent with the bathymetry of the Lake Washington adjacent to the project area, which indicates an alluvial fan extending across the lake to Mercer Island. Based on the bathymetry, this alluvial fan extends to a depth of at least 80 feet below mean sea level (MSL). The alluvial fan is expected to become less thick moving inland.

Typical sections through the project area are shown on Figures 2-1 and 2-2. The first section extends approximately parallel to the lake shoreline and the second extends approximately perpendicular to the first from the Pan Abode property in a northwesterly direction into Lake Washington. Elevation contours of the bottom of the silt-peat layer and the bottom of the sand layer are shown in Figures 2-3 and 2-4, respectively.

The present geologic interpretation is consistent with the geologic interpretation presented in the Quendall Terminals remedial investigation report (Hart Crowser, 1996), with only minor modifications based on more recent borings in the project area. The interpretation differs from an interpretation presented in a remedial investigation report for the Baxter property (Woodward-Clyde Consultants, 1990).. In that report, a confining layer was identified between the silt-peat layer and the deeper sand and gravel layer. More recent investigations by Hart Crowser and RETEC indicate that there is no continuous confining layer in the project area, although localized clay lenses are present.

3 Water Levels

Water levels at the site have been measured at a number of wells on the Baxter, Quendall, and Pan Abode properties, which comprise most of the project area. Water levels in the project area are quite stable with seasonal variations of less than 3 feet in most shallow wells (completed in the silt-peat layer) and less than 2 feet in the deeper sand and gravel layer. The fluctuation in the sand and gravel layer is approximately the same as the fluctuation in the Lake Washington water level. This indicates that the shallow layer is more influenced by seasonal changes in recharge and that the deep layer is more influenced by the water level in Lake Washington.

For model calibration, average water levels will be used to represent steady-state flow and long-term transport conditions. Average water level data are presented in Table 3-1 and shown for the silt-peat layer and sand layer in Figures 3-1 and 3-2, respectively.

4 Compounds of Concern

Chemical compounds detected in groundwater in the study area include BTEX compounds, PAHs, and pentachlorophenol. The compounds were compared based on maximum observed concentration, frequency of detection, exceedance of applicable surface water criteria, and the cancer slope factor for carcinogens. The results of the analysis are presented in Table 4-1.

This analysis is used to limit the number of compounds that will be simulated in a future transport evaluations for the study area. Based on this analysis, it is proposed that future transport evaluations will be limited to benzene, naphthalene, and chrysene. Benzene represents the transport behavior of light, volatile constituents. In addition, it is found at relatively high concentrations and is a carcinogen. Naphthalene represents the transport behavior of the two and three ring PAHs. It is found in relatively high concentrations and is more readily transported than three ring PAHs. Chrysene is representative of the heavy PAHs consisting of four or more rings. It is found at relatively high concentrations and is a carcinogen.

5 Model Setup

Application of a groundwater flow and transport model has been proposed as part of the feasibility analysis of the Port Quendall Development project area. The model can be used to estimate the mass loading rate of compounds to Lake Washington and to evaluate remedial alternatives for the project area. The USGS groundwater flow model, MODFLOW (McDonald and Harbaugh, 1988), and the SSP&A transport model, MT3D_96 (SSPA, 1996), are proposed for this modeling effort. Both models are appropriate models for this type of analysis and are recognized as industry standards for groundwater flow and transport modeling. The following sections describe the proposed setup for the groundwater model and preliminary estimates of model parameters.

5.1 Model Area

The area covered by the groundwater model will be the entire alluvial fan of May Creek extending from the toe of the bluff east of Interstate 405 and south to the mouth of the May Creek valley at approximately North 40th Street. The west boundary of the model area will be the toe of the alluvial fan in Lake Washington allowing simulation of flow from the sand and gravel layer to the lake and simulation of remedial alternatives that extend into the lake. The model area is shown on Figure 5-1 along with surface and bathymetric contours for reference.

Thickness of the silt-peat layer and sand layer for the model was computed from the surface, bottom of silt-peat, and bottom of sand contours. The results are shown in Figures 5-2 and 5-3 for the silt-peat and sand layers, respectively.

5.2 Model Grid and Layers

A variable spaced grid is proposed for the model with cell sizes ranging from 60 to 30 feet (Figure 5-4). The fine grid area covers most of the upland and nearshore portion of the project area. The coarse grid area includes areas around the project area including upland areas and off shore areas. The minimum grid size was selected to allow detailed simulation of containment walls, treatment zones, and funnel-and-gate technologies which may be analyzed as part of the feasibility analysis. If necessary, additional finer mesh areas can be added with a limited effort if the simulation of particular technologies require extremely fine grid cells.

Model layers are not yet defined, but will be based on site geology and remedial alternatives to be analyzed. At a minimum, model layers will represent the shallow silt-peat layer as well as the deep sand and gravel layer. It is likely that the sand and gravel layer will be divided into more than one layer for consideration of containment walls of different depths. The shallow layer may or may not be divided depending on the need to simulate remedial alternatives considered for the shallow layer. The fill layer will not be included in the model as this layer is unsaturated over most of the site and, in areas where the bottom of fill is below the water table, it will be treated as part of the silt-peat layer.

5.3 Boundary Conditions

The boundaries of the site are quite simple and heavily dominated by Lake Washington. The water levels in Lake Washington are very stable with time and the lake is large enough that the lake stage is not affected by groundwater flow at the project area. Similarly, remedial alternatives that may include pumping groundwater will not affect lake stage. Consequently, the lake will be treated as a constant head boundary.

For the upland boundary of the model, it is proposed to use different boundaries in the different layers. The shallow silt-peat layer extends to the toe of the bluffs east of Interstate 405 where the material is largely silt and clay. The silt and clay along the bluff is considered to contribute little groundwater flow to the site. Consequently, the upland boundary in the shallow layer will be a no-flow boundary.

The deep sand and gravel layers extend up to the alluvial deposits in May Creek south of North 40th Street and may be hydraulically connected to sandy aquifers under the bluffs east of Interstate 405. These boundaries are not considered to be significantly affected by pumping in the project area. Consequently, the model layers in the deep sand and gravel layer will be treated as constant head boundaries (see Figure 5-4). This is a conservative assumption as it means that the boundary will not inhibit flow in the model.

In addition to the above model boundaries, the model will include May Creek and surface recharge as additional sources of groundwater. Recharge will be based on an estimate of surface runoff, precipitation, and evapotranspiration and is expected to be about 20 inches per year. May Creek will be treated as a river boundary which will allow inflow or outflow from May Creek to groundwater depending on the head difference between May Creek and the water table.

5.4 Hydraulic Parameters

Hydraulic parameters include hydraulic conductivity and storage coefficient. Because the groundwater flow model will be operated under steady-state conditions, only the hydraulic conductivity is pertinent to this study. Hydraulic conductivity has been measured through pump tests and slug tests on both the Quendall Terminal property and the Baxter property. The results of these tests are presented in Table 5-1.

The results of the hydraulic testing on both the Quendall and Baxter properties are in good agreement. The testing indicates similar ranges of hydraulic conductivity depending on the material type. Sand and sandy gravel in either the deep or shallow layers show hydraulic conductivities in the range of 6 to 57 ft/day. Silty sand has hydraulic conductivities in the range from 0.2 to less than 10 ft/day. Hydraulic conductivity for silt and clay ranges from 0.2 to 2.0. The overlap in the ranges for hydraulic conductivity between sand, silty sand, and silt is largely due to a single, possibly anomalous measurement. If the lowest hydraulic conductivity for sand and the highest for silt sand were deleted, the range for sand would be from 15 to 57 ft/day and the range for silty sand would be from 0.2 to 8.8 ft/day. Similarly, the range of hydraulic conductivity for silt or clay is less than 1.0 if the highest measured value is deleted.

The range of hydraulic conductivity indicates that the material on the site is quite heterogeneous. Based on the geologic interpretation, the heterogeneity may be due to remnants of May Creek channels or differential deposition during periods of high lake levels. Also based on the geologic model for the study area, it is expected that heterogeneity will be greater in the vertical direction than in the horizontal direction.

In the model, it is proposed to incorporate the hydraulic conductivity data by averaging the data over each layer instead of attempting to discern zones or regions of varying hydraulic conductivity within a layer. For the horizontal conductivity, it is proposed to take the arithmetic average of the data (Table 5-1). This represents flow in a layered system with horizontal flow predominantly through coarser-grained layers. The hydraulic conductivity in the vertical direction will be taken as a fraction of the horizontal hydraulic conductivity. To represent the low hydraulic conductivity of silt and peat layers, it is expected that the ratio between the horizontal and vertical hydraulic conductivity will be on the order of 100. For the sand layer, the vertical layering is less prominent and the ratio is expected to be on the order of 10.

In addition to the hydraulic parameters for the flow model, the effective porosity is also needed for transport modeling. The effective porosity for the silt-peat layer has been estimated at between 0.28 and 0.32 at the Baxter property and at 0.30 at the Quendall Terminals property. The effective porosity of the sand has been estimated at between 0.20 and 0.25 at both properties. For all practical purposes, the values estimated for effective porosity at each property are the same and little effect is expected in model results over the ranges estimated for each property.

5.5 Chemical Parameters

Chemical parameters consist of chemical-specific reaction rates and sorption coefficients for the transport modeling. Chemical parameters will be estimated from the literature. In addition, the literature values will be augmented with site-specific data derived from treatability testing currently in progress. Chemical parameters have a high level of uncertainty and efforts will be made to identify a realistic range of values based on site-specific data and literature values. The model will be implemented with different values of the transport parameters to assess the sensitivity of the model results to changes in transport parameters.

6 References

Hart-Crowser, Inc. 1996. Draft Remedial Investigation, Quendall Terminals Upland, Renton, Washington. Prepared for Quendall Terminals.

McDonald, M.G. and A.W. Harbaugh. 1988. A Modular Three-dimensional Finite-difference Groundwater Flow Model. U.S. Geological Survey, Reston, Virginia.

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S.S. Papadopulos & Associates. 1996. MT3D_96: A Modular Three-dimensional Transport Model for Simulation of Advective, Dispersion and Chemical Reactions of Contaminants in Groundwater Systems. S.S. Papadopulos & Associates, Bethesda, Maryland.

Woodward-Clyde Consultants. 1990. Remedial Investigation Report, J.H. Baxter Renton Site. Prepared for J.H. Baxter, Inc.

Figures and Tables

Figures

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5-3 Sand layer thickness
5-4 Model grid and boundary conditions

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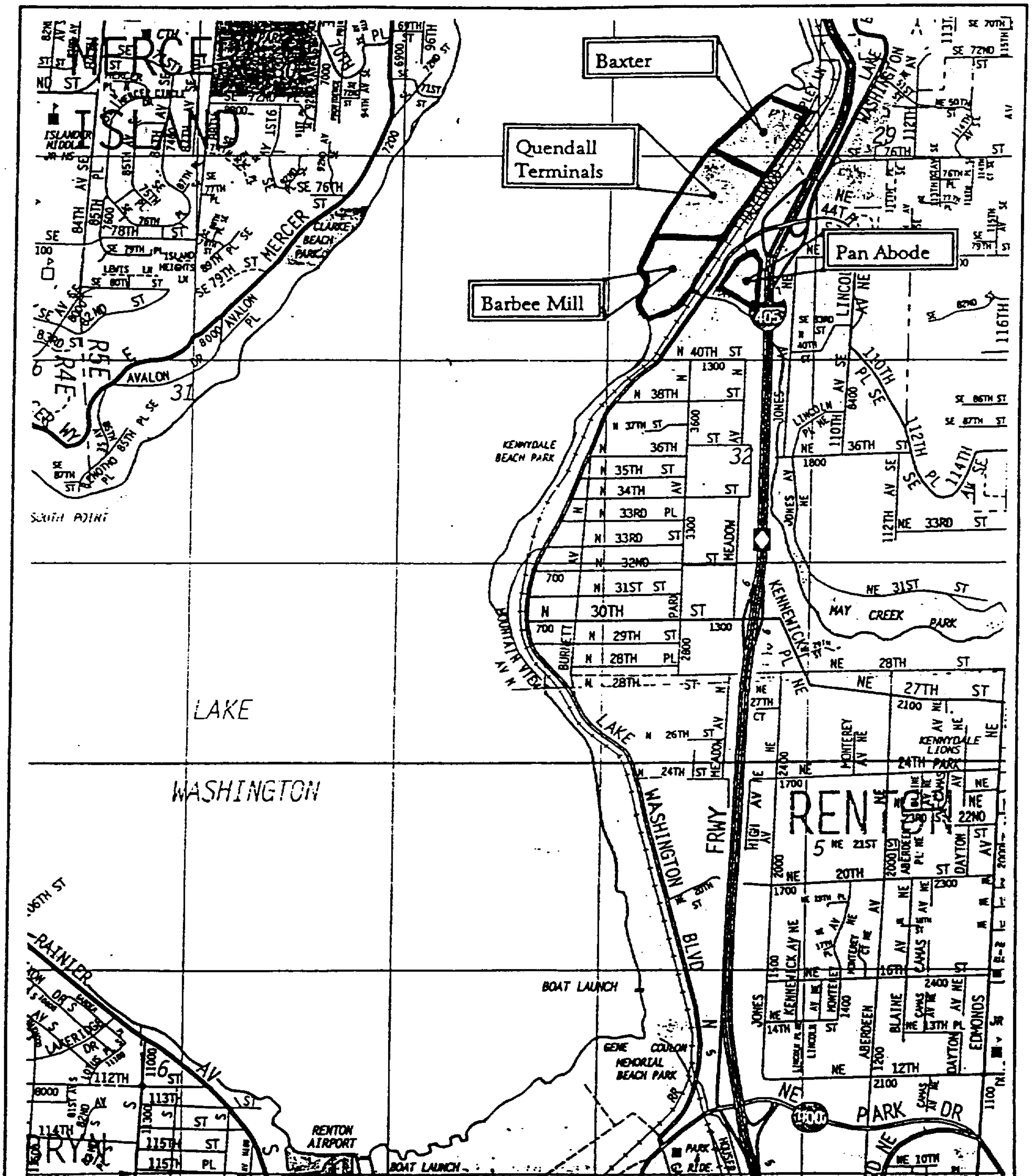
3-1 Average water level data
4-1 Compounds of concern
5-1 Hydraulic properties from other investigations

RETEC

Figure 1-1 Site Location Map



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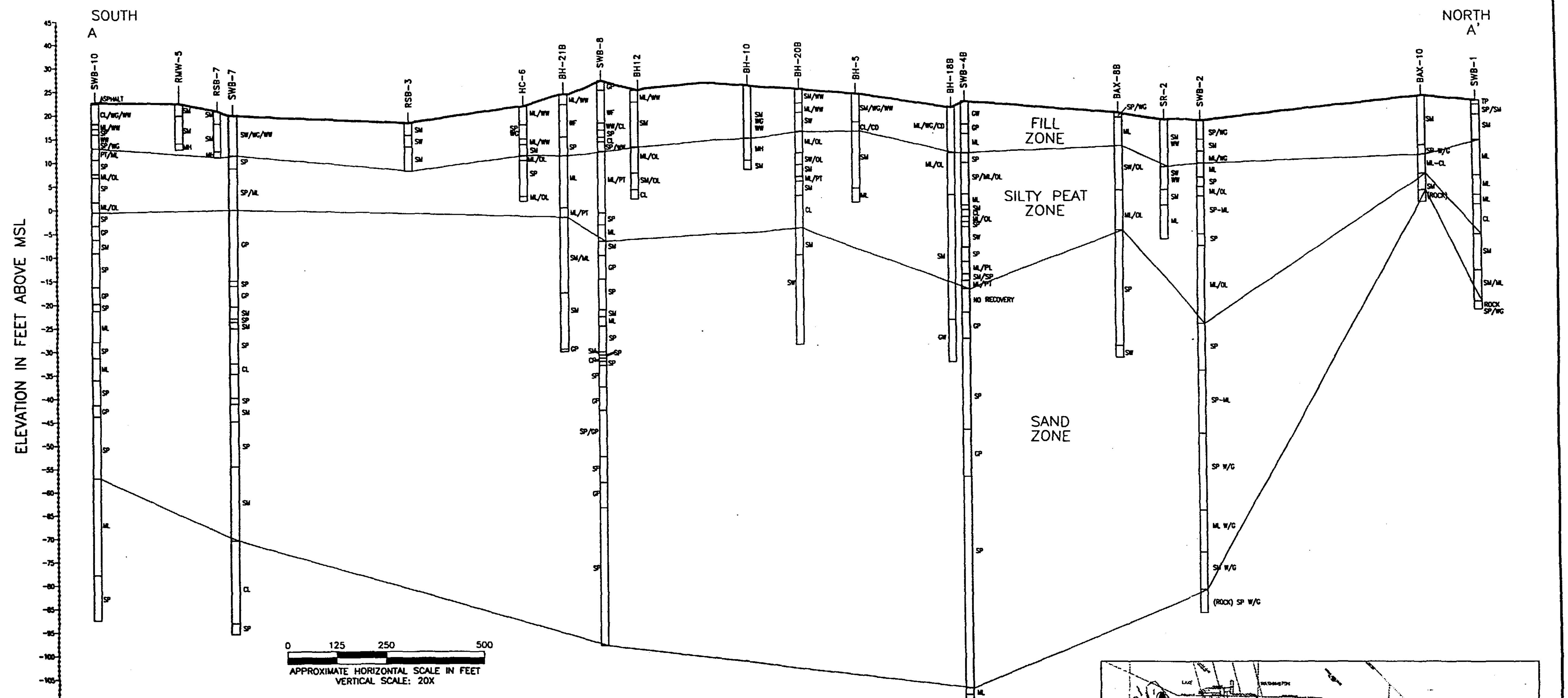

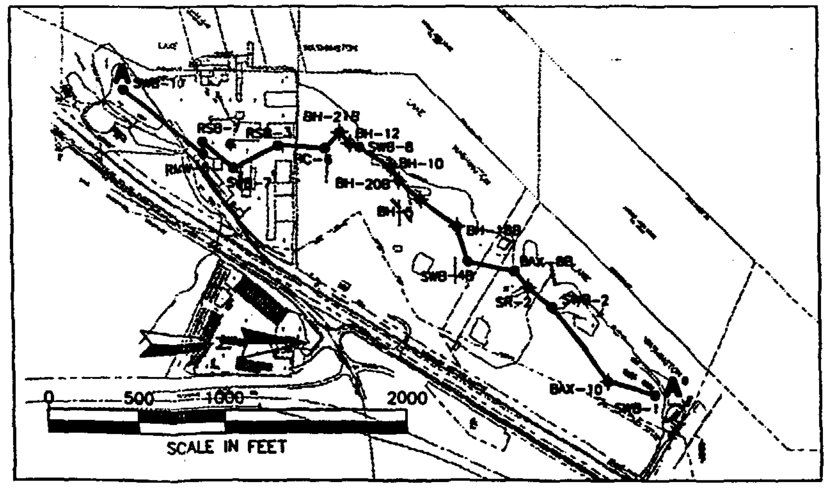

NOTES

FILL ZONE

INCLUDES (1) DREDGED FILL CONSISTING OF LOOSE-TO-MEDIUM DENSE WET SILTY FINE SAND, OR FINE TO MEDIUM SAND, AND (2) DUMPED FILL CONTAINING CLAY, SILT, SAND, GRAVEL, RUBBLE, WOOD AND OTHER DEBRIS. THE DREDGED FILL MAY BE PRESENT ALONG THE FORMER LAKE WASHINGTON SHORELINES AND APPEAR SIMILAR TO THE MAY CREEK DELTAIC DEPOSITS.

SILTY PEAT ZONE

CONSISTS OF SOFT TO STIFF, DARK BROWN TO GRAY SILTY PEAT, ORGANIC WOODY SILT, AND SILTY FINE SAND WITH INTER BEDDED GRAY TO BROWN CLAY, SILT, SAND, AND OCCASIONAL ASH LENSES.

SAND ZONE

CONSISTS OF GRAY DENSE, TO MEDIUM DENSE, FINE TO COARSE GRAINED SAND, AND GRAVEL WITH COBBLES, AND INTER BEDDED GRAY SILTY FINE GRAINED SAND, AND SILT LENSES.

LEGEND

ML=SILT/SANDY SILT	WG= WITH GRAVEL
MH=CLAYEY SILT	GW=WELL GRADED GRAVEL
OL=ORGANIC SILT	GP=POORLY GRADED GRAVEL
CL=LEAN CLAY	SW=WELL GRADED SAND
CH=FLAT CLAY	SP-SM=POORLY GRADED
WF=WHITE FLY ASH	SM=SILTY SAND
WW=WOOD WASTE	SC=CLAYEY SAND
PT=PEAT	CD=CONSTRUCTION DEBRIS

NO	DRWN	DATE	REVISION
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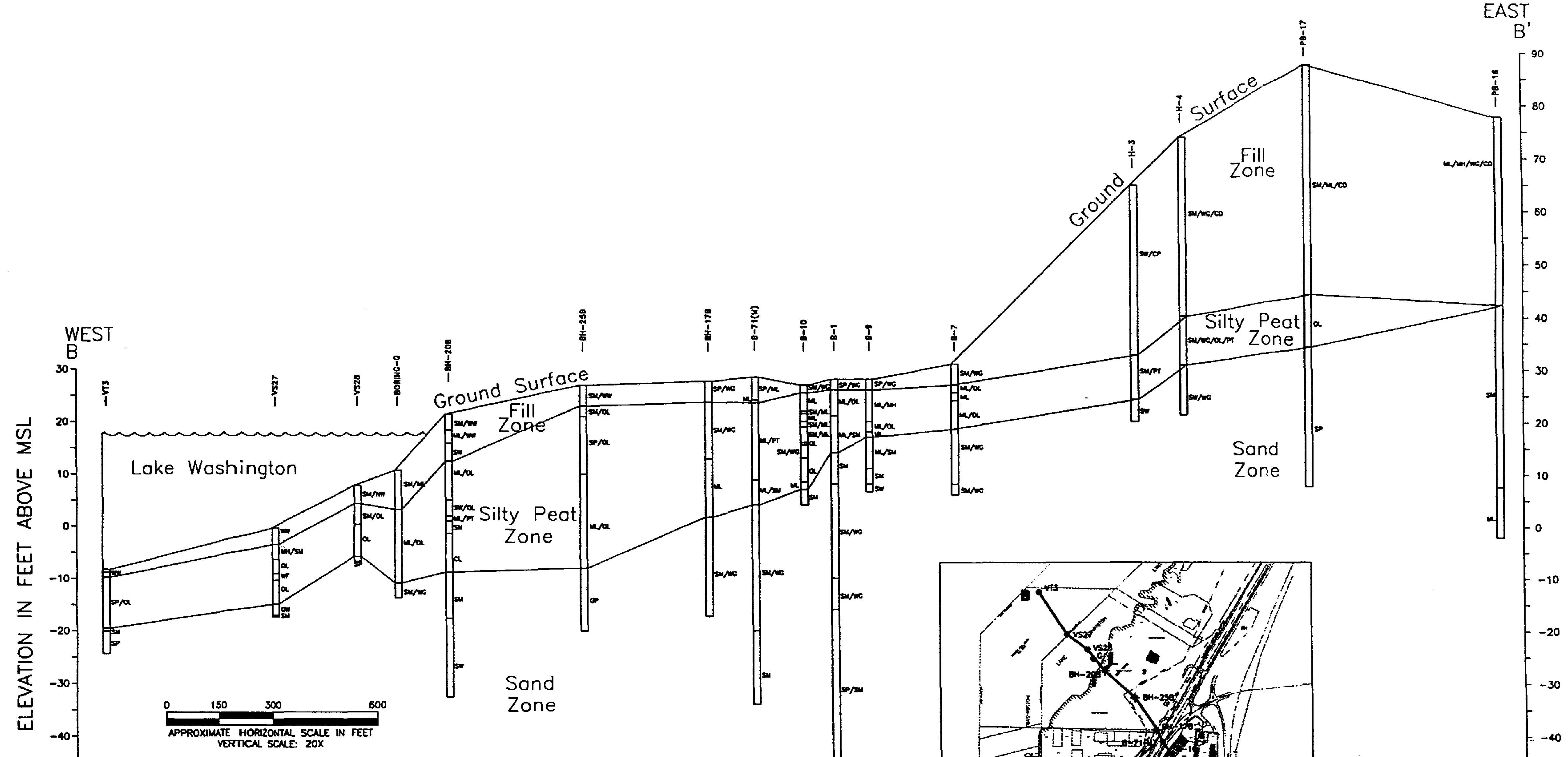
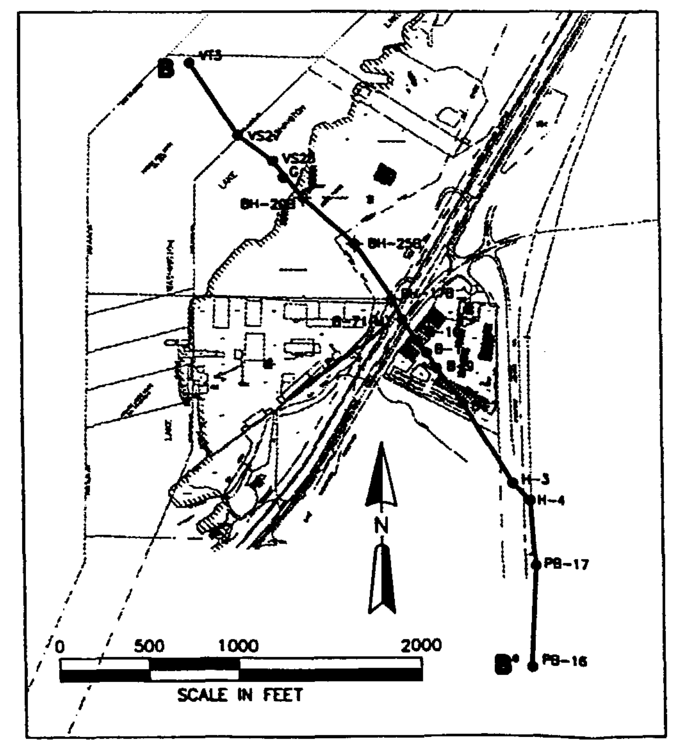
CURRENT DATE: NONE — CAD FILE 24380145

PORT QUENDALL
NORTH-SOUTH SITE
CROSS SECTION

RETEC REMEDIATION TECHNOLOGIES INC

FIGURE 2-10





NOTES

FILL ZONE

INCLUDES (1) DREDGED FILL CONSISTING OF LOOSE-TO-MEDIUM DENSE WET SILTY FINE SAND, OR FINE TO MEDIUM SAND, AND (2) DUMPED FILL CONTAINING CLAY, SILT, SAND, GRAVEL, RUBBLE, WOOD AND OTHER DEBRIS. THE DREDGED FILL MAY BE PRESENT ALONG THE FORMER LAKE WASHINGTON SHORELINES AND APPEAR SIMILAR TO THE MAY CREEK DELTAIC DEPOSITS.

SILTY PEAT ZONE

CONSISTS OF SOFT TO STIFF, DARK BROWN TO GRAY SILTY PEAT, ORGANIC WOODY SILT, AND SILTY FINE SAND WITH INTER BEDDED GRAY TO BROWN CLAY, SILT, SAND, AND OCCASIONAL ASH LENSES.

SAND ZONE

CONSISTS OF GRAY DENSE, TO MEDIUM DENSE, FINE TO COARSE GRAINED SAND, AND GRAVEL WITH COBBLES, AND INTER BEDDED GRAY SILTY FINE GRAINED SAND, AND SILT LENSES.

LEGEND

ML=SILT/SANDY SILT	WG= WITH GRAVEL
MH=CLAYEY SILT	GW=WELL GRADED GRAVEL
OL=ORGANIC SILT	GP=POORLY GRADED GRAVEL
CL=LEAN CLAY	SW=WELL GRADED SAND
CH=FLAT CLAY	SP-SM=POORLY GRADED
WF=WHITE FLY ASH	SM=SILTY SAND
WW=WOOD WASTE	SC=CLAYEY SAND
PT=PEAT	CD=CONSTRUCTION DEBRIS

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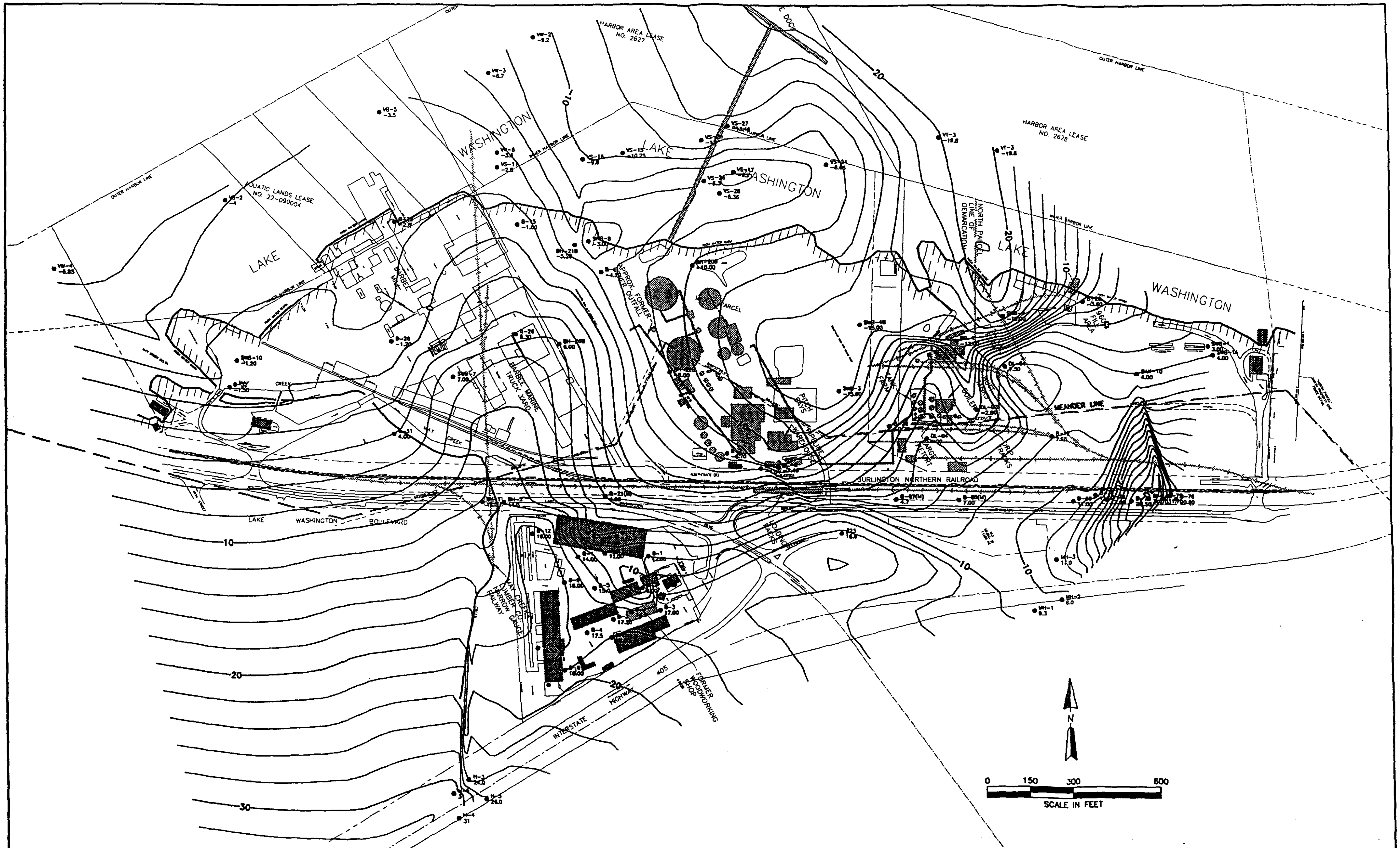
PORT QUENDALL
EAST-WEST SITE
CROSS SECTION

RETEC
REMEDIATION TECHNOLOGIES INC

FIGURE 2-2 REV 0



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TOP OF SAND ELEVATIONS IN FEET ABOVE MSL

RETEC REMEDIATION TECHNOLOGIES INC

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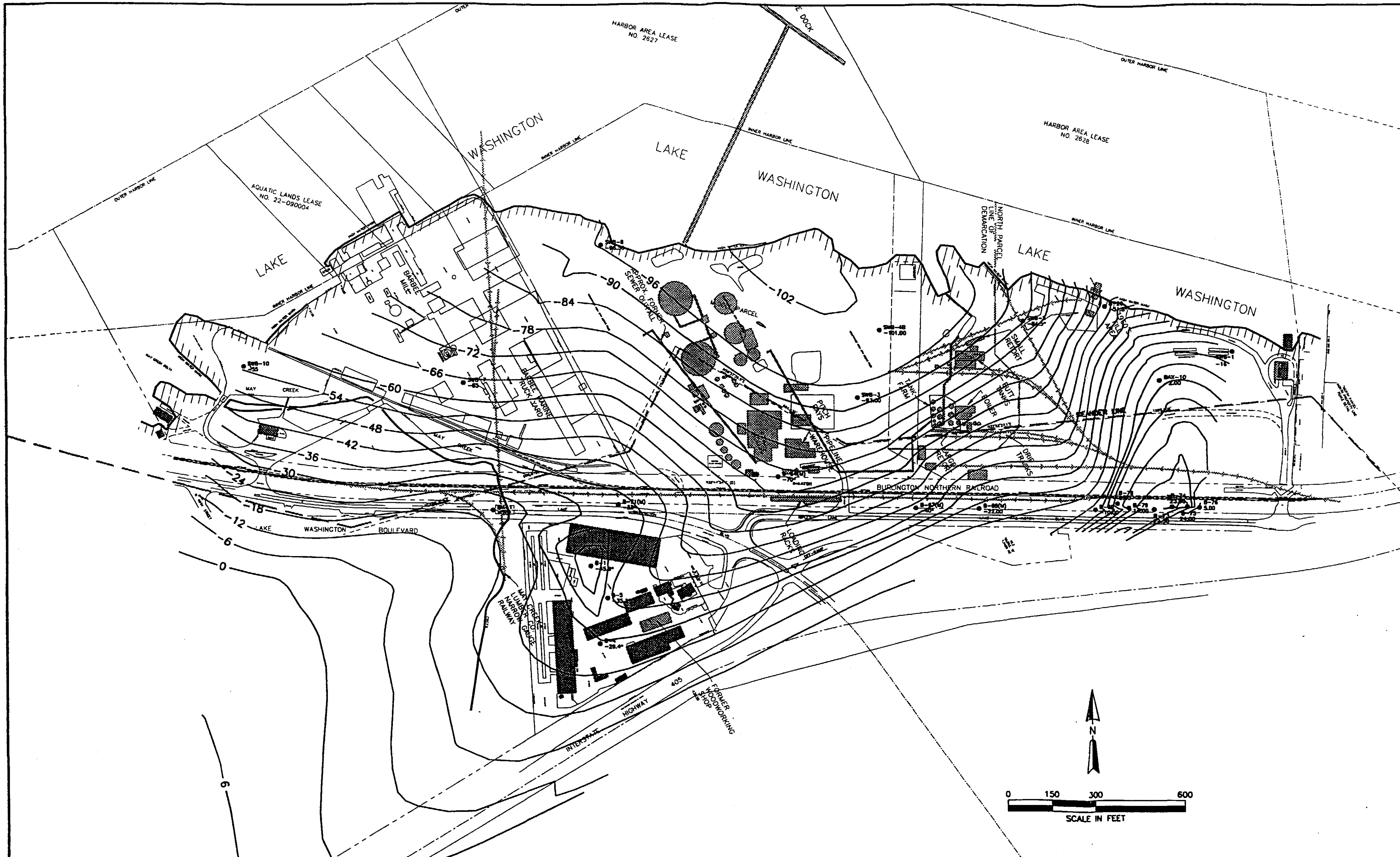

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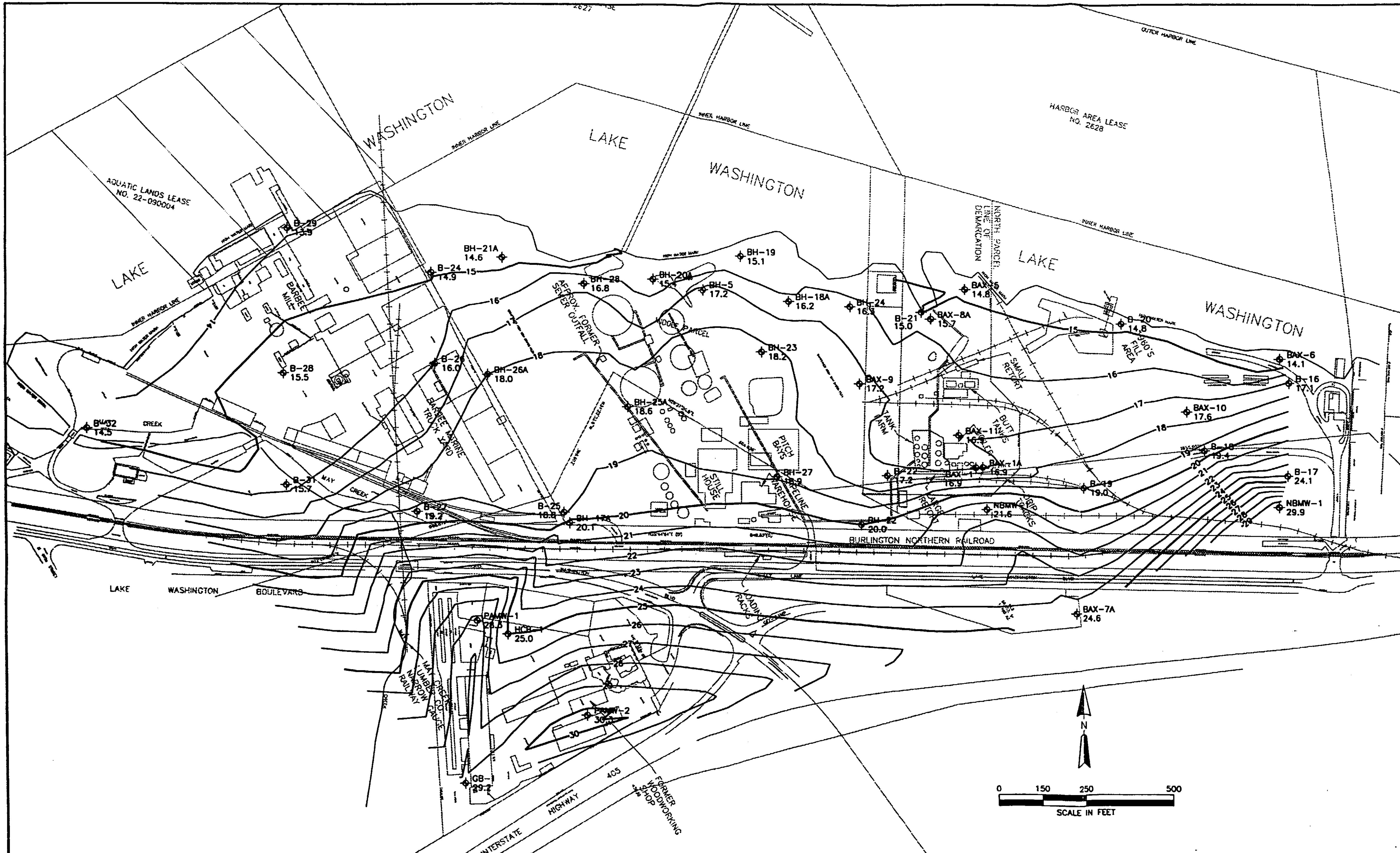
BOTTOM OF SAND ELEVATIONS
IN FEET ABOVE MSL

RETEC
REMEDIATION TECHNOLOGIES INC

DRAWING NO. FIGURE 2-4 | REV 0



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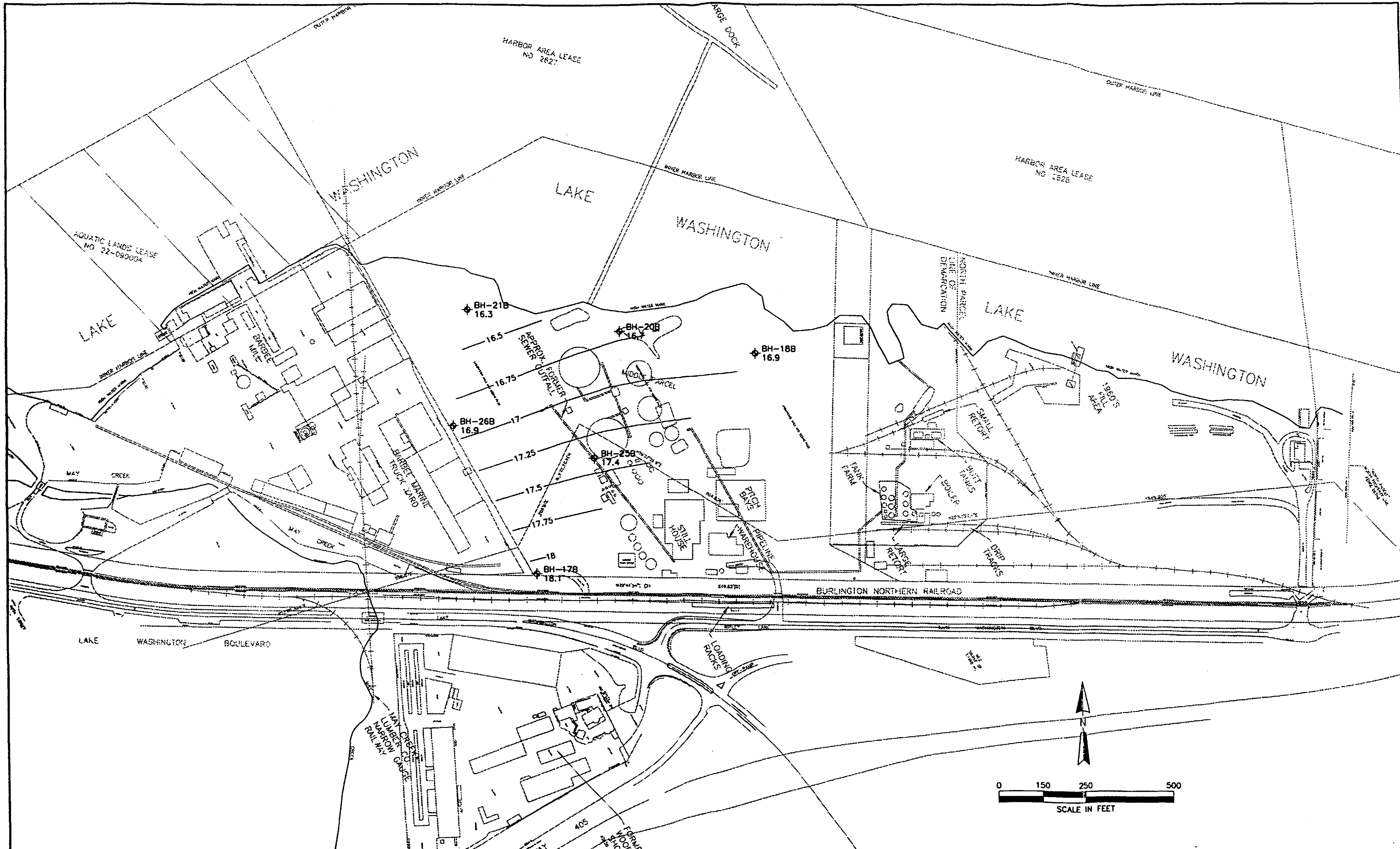
SHALLOW WATER LEVELS
ELEVATIONS IN FEET ABOVE MSL

RETEC REMEDIATION TECHNOLOGIES INC

DRAWING NO. FIGURE 3-1 REV 0



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DEEP WATER LEVELS
ELEVATIONS IN FEET ABOVE MSL

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REMEDIATION TECHNOLOGIES INC

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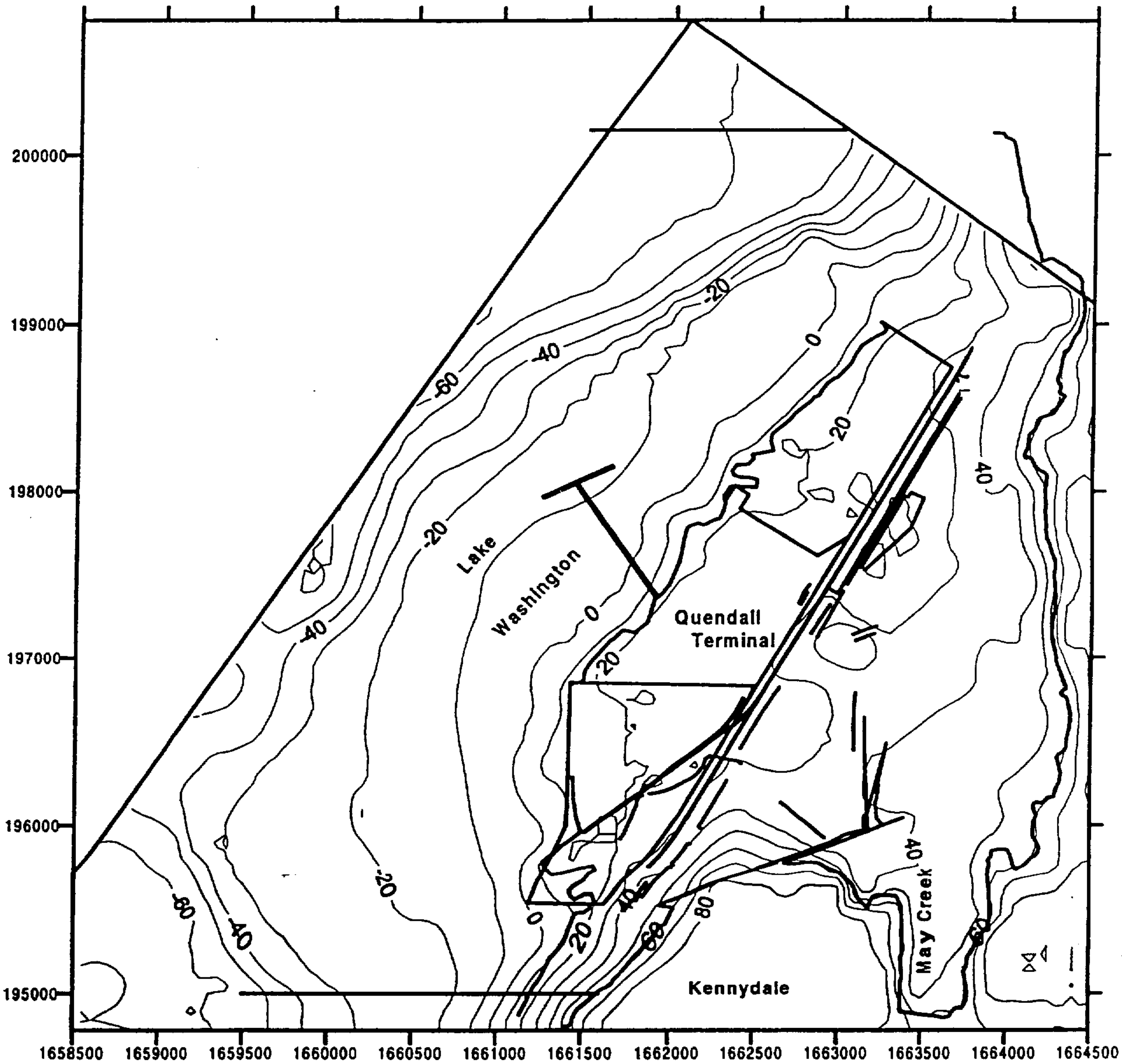
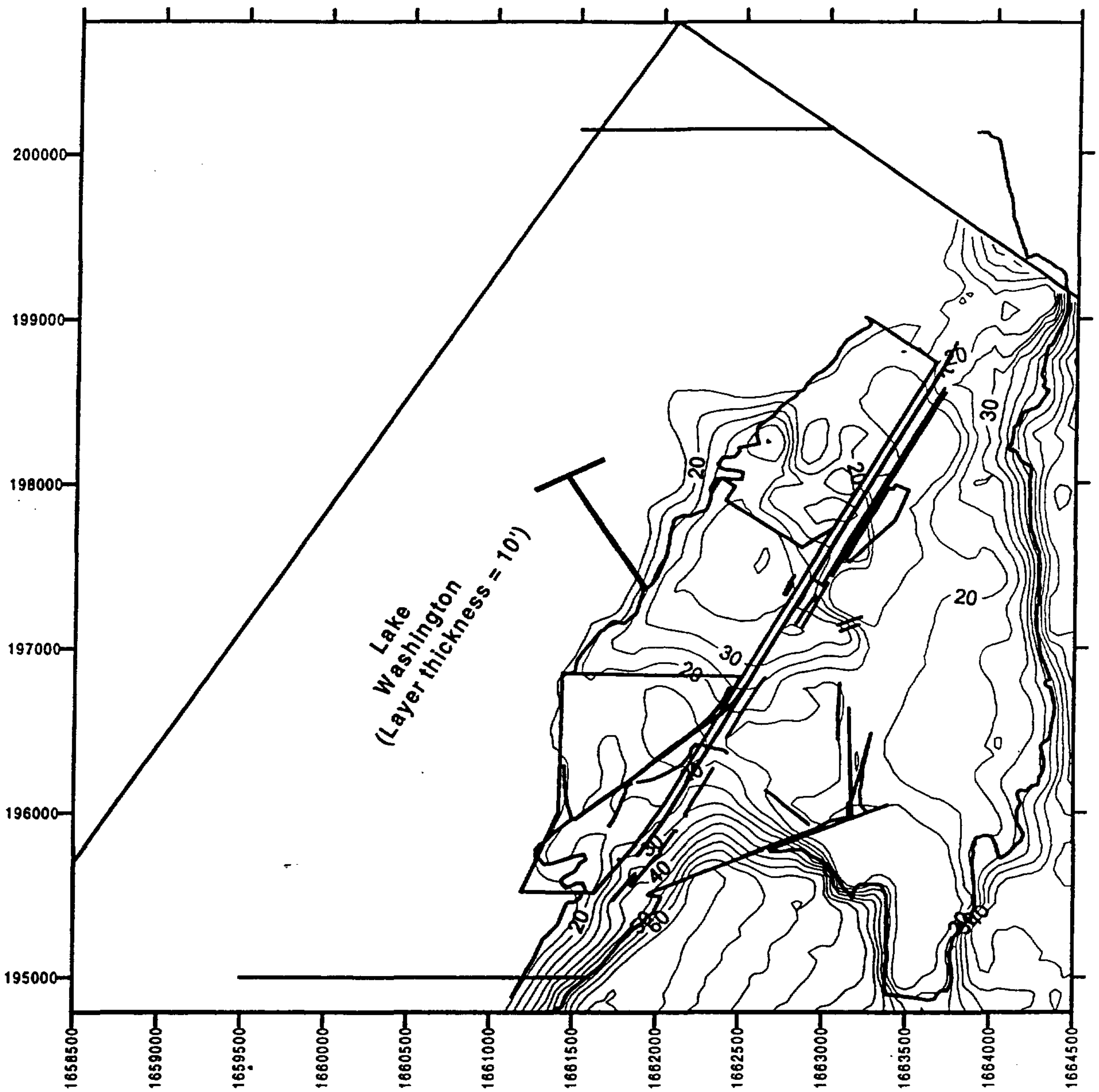


Elevations in feet MSL

S.S. PAPADOPULOS & ASSOCIATES, INC.
ENVIRONMENTAL & WATER-RESOURCE CONSULTANTS

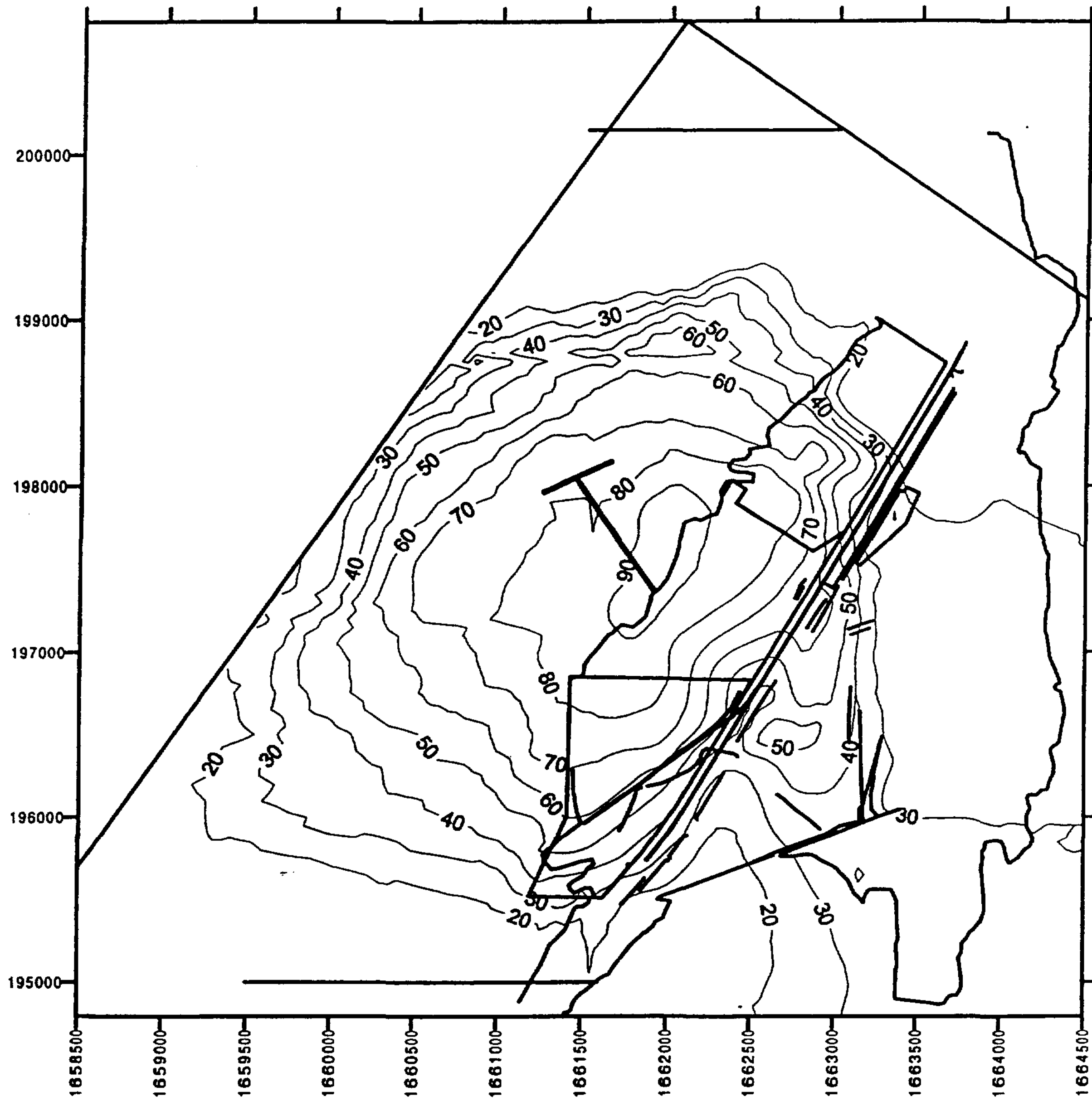
Ground-water model area and surface/bathymetric contours

5-1



Thickness in feet

S.S. PAPADOPULOS & ASSOCIATES, INC. ENVIRONMENTAL & WATER-RESOURCE CONSULTANTS	**Model layer thickness for silt-peat layer**	**5-2**

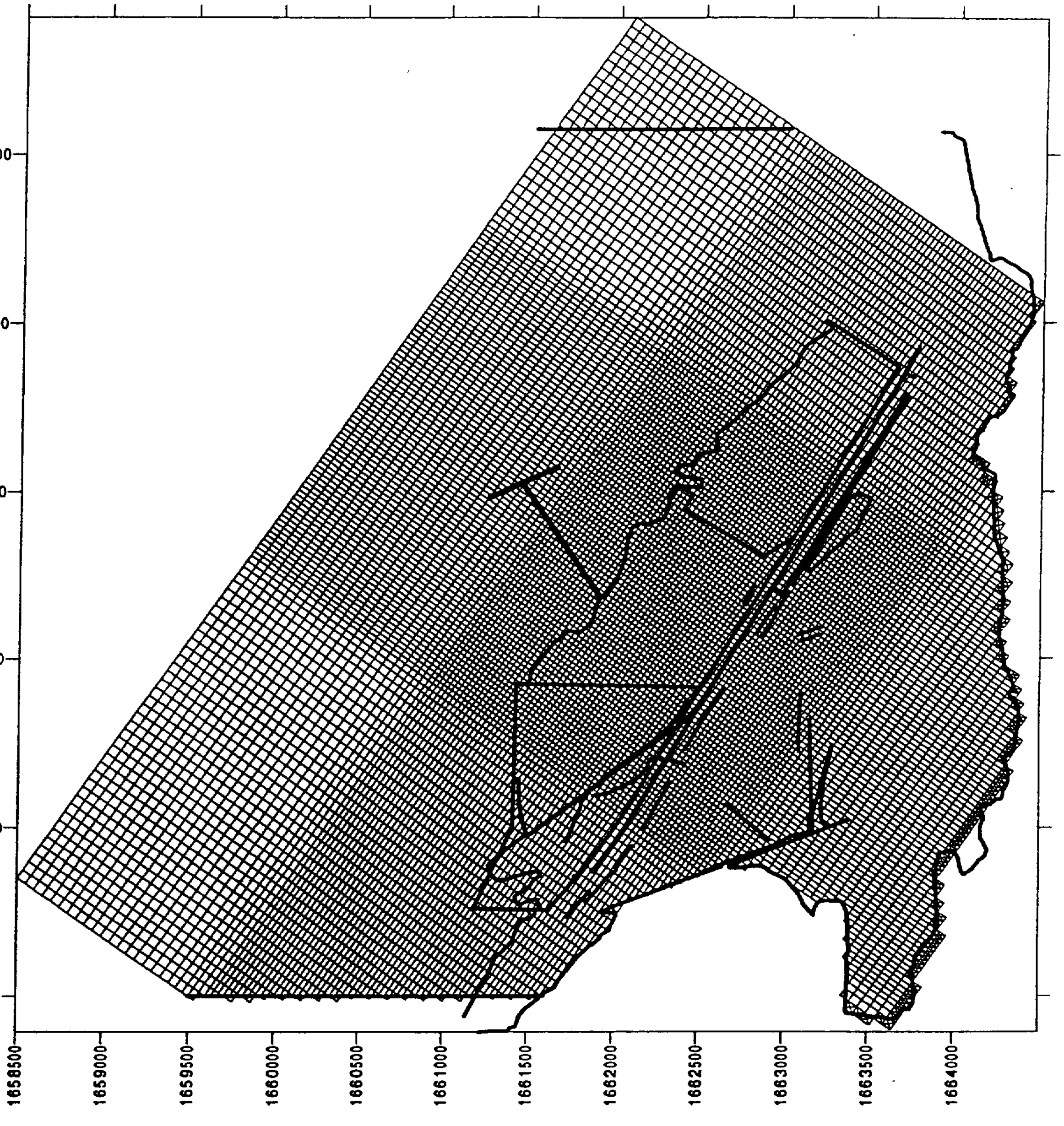


Thickness in feet

S.S. PAPADOPULOS & ASSOCIATES, INC.
ENVIRONMENTAL & WATER-RESOURCE CONSULTANTS

Model layer thickness for sand layer

5-3



S.S. PAPADOPULOS & ASSOCIATES, INC. ENVIRONMENTAL & WATER-RESOURCE CONSULTANTS	**Proposed model grid** **Hatched cells indicate constant head boundary**	5-4

RETEC

Table 4-1 Compounds of Concern in ground water samples

	Detections	Analyses	Detection %	Max. Conc (ug/L)	Solubility Limit mg/L	Retardation Factor	# of Rings	Reference Dose Mg/Kg/Day Oral	Ref.	Inhalation	Ref.	Cancer Slope Factor Mg/Kg/Day Oral	Ref.	Inhalation	Ref.	Carcinogen
Pentachlorophenol	3	130	2%	630	5mg/L@0'C / 14mg/L@20'C	7	1	3.00E-02	R	1.20E-01	R	-	R	-	R	No
Benzene	37	113	33%	14000	1780 mg/L@20'C	1	1	-	R	1.70E-03	R	2.90E-02	A	2.90E-02	A	Yes
Toluene	54	108	50%	3400	470mg/L@16'C / 515 mg/L@20'C	2	1	2.00E-01	A,R	1.14E-01	-	-	R	-	R	No
Ethylbenzene	38	113	34%	3800	140 mg/L@15'C / 152mg/L@20'C	6	1	1.00E-01	A	2.86E-01	A	-	R	-	R	No
o-Xylene	10	26	38%	510	175 mg/L@20'C	NA	1	2.00E+00	R	2.00E-01	R	-	R	-	R	No
m-,p-Xylene	12	26	46%	1000	198mg/L@25'C(p-xylene)	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	No
xylene (total)	44	106	42%	7800	NA			2.00E+00	A,R	2.00E+00	A	-	R	-	R	No
Naphthalene	72	121	60%	43000	31-34mg/L in distilled water@25'C	7	2	4.00E-03	A	4.00E-03	A	-	R	-	R	No
Acenaphthene	59	121	49%	1900	NA	23	3	6.00E-02	R	6.00E-02	R	-	R	-	R	-
Acenaphthylene	25	121	21%	2300	3.93 mg/L in distilled@25'C	13	3	4.00E-03	-	4.00E-03	-	-	-	-	-	No
Anthracene	35	121	29%	1200	.075 mg/L@15'C	69	3	3.00E-01	A	3.00E-01	R	-	R	-	R	No
Fluorene	56	121	46%	2200	1.9 mg/L@25'C	36	3	4.00E-02	A	4.00E-02	A	-	R	-	R	No
Phenanthrene	50	121	41%	6200	1.6mg/L@15'C	69	3	4.00E-03	-	4.00E-03	-	-	-	-	-	No
Benzo(a)anthracene	31	121	26%	1100	0.044mg/L@24'C (practical grade)	6,704	4	-	R	-	R	7.30E-01	R	6.10E-01	R	Yes
Chrysene	29	121	24%	1700	0.0015@15'C / 0.006mg/L@25'C	972	4	-	A	-	A	1.15	A	1.15	A	Yes
Fluoranthene	46	121	38%	2800	0.120mg/L@24'C (99%purity)	186	4	4.00E-02	A	4.00E-02	A	-	R	-	R	No
Pyrene	41	121	34%	2400	0.032mg/L (practical grade)	186	4	3.00E-02	R	3.00E-02	R	-	R	-	R	No
Benzo(a)pyrene	33	121	27%	1700	NA	26,715	5	-	R	-	R	7.3	R	6.1	R	Yes
Benzo(b)fluoranthene	14	47	30%	50	NA	2,672	5	-	R	-	R	7.30E-01	R	6.10E-01	R	Yes
Benzo(k)fluoranthene	12	59	20%	46	NA	2,672	5	-	R	-	R	7.30E-02	R	6.10E-02	R	Yes
Dibenz(a,h)anthracene	14	121	12%	420	NA	16,030	5	-	R	-	R	7.3	R	6.1	R	Yes
Benzo(g,h,i)perylene	15	121	12%	1000	NA	7,772	6	4.00E-03	-	4.00E-03	-	-	-	-	-	No
Indeno(1,2,3-cd)pyrene	14	76	18%	830	NA	7,772	6	-	-	-	-	7.30E-01	-	6.10E-01	-	Yes
Dibenzofuran	37	99	37%	1500	NA	55		4.00E-03	R	-	R	-	R	-	R	No

NOTES:
The detections and analysis statistics are compiled from the Retec database for Quendall Properties
Retardation factors are tabulated in Table XX, shown in appendix XX.

References
R - US EPA Region III Risk Based Concentration Table, EPA Region 3, March 7, 1995
A - Emergency Standard Guide for Risk Based Corrective Action Applied at Petroleum Release Sites, ASTM, ES 38-94
Solubility Limit taken from "Handbook of Environmental Data on Organic Chemicals, 2nd Edition, Karel Verschueren, Van Nostrand Reinhold, New York, 1983

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Table 5-1 Summery of Hydraulic Conductivity Estimates based on pumping test and slug tests

Test Location	Hydraulic Conductivity (ft/day)	Type of Test	Depth below Ground Surface of Screen Interval	Type of Soil in Screened Interval	Geologic Unit as Assigned by Retec	Reference
BAX-1A	2.1	slug test	5 to 20	silty sand	Fill and Silty Peat Zone	2
BAX-5	0.6	slug test	8 to 18	silty sand and sand	Fill and Silty Peat Zone	2
BAX-8A	15.0	slug test	10 to 20	sand	Silty Peat Zone	2
BAX-9	31.2	pumping test	5 to 15	silty sand with silty and clay layer	Fill and Silty Peat Zone	1
BAX-10	1.5	slug test	10 to 20	sand and silty sand	Silty Peat Zone	2
BH-10	3.4	pumping test	5 to 20	silty sand with layer of clayey silt	Fill and Silty Peat Zone	1
BH-15	4.8	pumping test	5 to 20	silty sand	Fill and Silty Peat Zone	1
BH-18A	0.6	slug test	4 to 14	silt	Fill and Silty Peat Zone	1
BH-2A	1.1	pumping test	? to 20	silty sand with peat interbeds	Silty Peat Zone	1
BH-6	8.8	pumping test	8 to 18	silty sand and silty clay with peat	Silty Peat Zone	1
BH-8	0.4	pumping test	13 to 23	silty clay with layer of silty sand	Silty Peat Zone	1
BH-19	15.6	pumping test	5 to 15	sand with layer of silt	Silty Peat Zone	1
BH-25A	6.8	pumping test	9 to 19	sand and silty sand with layer of silt	Silty Peat Zone	1
BH-12	2.2	slug test	13 to 23	sandy/clayey silt and very silty sand	Silty Peat Zone	1
BH-17A	0.2	slug test	6 to 16	sand to very silty sand with layer of silt	Silty Peat Zone	1
BH-19	17.0	slug test	5 to 15	sand with layer of silt	Silty Peat Zone	1
BH-20A	17.0	slug test	7 to 22	interbedded layer of silts	Silty Peat Zone	1
BH-23	0.2	slug test	7 to 22	silt with small layer of sand	Silty Peat Zone	1
WP-1	23.0	slug test	2 to 3(3)	sand	Silty Peat Zone	1
WP-4	0.5	slug test	2 to 3(3)	silt	Silty Peat Zone	1
WP-5	20.1	slug test	2 to 3(3)	sand	Silty Peat Zone	1
BH18B	56.7	slug test	42 to 52	sandy gravel	Sand Zone	1
BH-21B	5.7	slug test	42 to 52	gravelly f-m sand	Sand Zone	1

NOTES:

1. Draft Remedial Investigation, Quendall Terminal Uplands, Table 3-2, Hart Crowser Report, October 1, 1996.
2. Remedial Investigation Report, J.H. Baxter, Renton Washington Site , Vol I, Woodward Clyde, October 1996.
3. Feet below mudline at offshore temporary well points.

Table 3-1 Average measured water level data.

Well ID	Coordinates East-West	Coordinates North-South	Model Layer	Water Level (ft MSL)
16	1662544	198027	Silt-peat	17.05
17	1662463	198084	Silt-peat	24.1
18	1662377	198121	Silt-peat	19.35
19	1662520	198141	Silt-peat	18.95
20	1662625	198089	Silt-peat	14.75
21	1662696	198039	Silt-peat	15
22	1662945	197975	Silt-peat	14.9
25	1662870	198024	Silt-peat	18.75
26	1662772	198079	Silt-peat	16
27	1662689	198134	Silt-peat	16
28	1662606	198185	Silt-peat	19.2
29	1662941	198087	Silt-peat	13.85
31	1663023	198037	Silt-peat	15.65
32	1662747	198269	Silt-peat	14.45
B-1	1662691	196518	Silt-peat	22.3
B-3	1662949	196509	Silt-peat	22.4
BAX-1	1662958	197926	Silt-peat	16.88
BAX-10	1663122	198530	Silt-peat	17.55
BAX-11	1662854	197932	Silt-peat	16.88
BAX-1A	1662967	197944	Silt-peat	16.91
BAX-5	1662502	198159	Silt-peat	14.77
BAX-6	1663129	198833	Silt-peat	14.13
BAX-7A	1663462	197963	Silt-peat	24.6
BAX-8A	1662527	198031	Silt-peat	15.7
BAX-9	1662585	197762	Silt-peat	17.16
BH-12	1661825	197122	Silt-peat	18.33
BH-17A	1662512	196838	Silt-peat	20.13
BH-18A	1662281	197707	Silt-peat	16.24
BH-19	1662102	197650	Silt-peat	15.07
BH-20A	1662029	197396	Silt-peat	15.4
BH-21A	1661758	197052	Silt-peat	14.62
BH-22	1662937	197562	Silt-peat	19.96
BH-23	1662367	197566	Silt-peat	18.23
BH-24	1662381	197850	Silt-peat	16.34
BH-25A	1662307	197149	Silt-peat	18.61
BH-26A	1662026	196848	Silt-peat	17.96
BH-27	1662698	197423	Silt-peat	18.88
BH-28	1661940	197219	Silt-peat	16.82
BH-5	1662129	197508	Silt-peat	17.17
BH-5A	1662110	197486	Silt-peat	17.17
GB-1	1663000	196205	Silt-peat	29.2
HCB-1	1662697	196522	Silt-peat	25
NBMW-1	1663078	197893	Silt-peat	21.6
NBMW-2	1663488	198618	Silt-peat	29.93
PAMW-1	1662620	196466	Silt-peat	28.34
PAMW-2	1663009	196605	Silt-peat	30.32
BH-17B	1662511	196838	Sand	18.14
BH-18B	1662281	197707	Sand	16.89
BH-20B	1662028	197395	Sand	16.66
BH-21B	1661757	197052	Sand	16.26
BH-25B	1662306	197149	Sand	17.45
BH-26B	1662025	196847	Sand	16.94

ITERATIVE PROCESS

To: Brian Sato

From: Ching-Pi Wang

Date: April 22, 1997

Subj: Baxter/Quendal/JAG
Comments on Site Groundwater Model Memorandum dated April 4, 1997.

1. Page 2. "Modeling Objectives"

State the opinions and conclusions of Retec and S. S. Papadopulos & Associates on quality of results of the two-dimensional flow path model. Identify the results and interpretations from the two-dimensional model that will be utilized in three-dimensional model. For example, what is the depth of vertical flow components? What is the distance from the shore that the lake environment might be affected by contaminated groundwater discharge?

2. Page 3. "Water Levels"

This section is a bit misleading. Clarify the section by including the following:

- o Lake Washington water level is artificially controlled twice a year. State the magnitude of change and effect on ground water.
- o Ground-water levels in the shallow layer are affected by seasonal recharge and biannual changes in lake levels. Retec and S. S. Papadopulous & Associates cannot separate out the component of shallow water level fluctuations due to seasonal recharge and changes lake level.
- o Provide readers with an understanding of the hydraulic interconnection between the shallow and deep layers. Or, refer readers to documents where this is discussed in detail.

3. Page 3 and 4. "Water Levels"

a. Calibrate water levels to average and actual measured levels. For example, calibrate model to measured levels shown on Figures 3-1 and 3-2. Identify any differences in calibration results.

b. Clarify how long-term transport will be used to calibrate model. For example, provide figure that shows model simulation of historical and present day contaminant distribution at ground-water monitoring wells. A model to be used to predict future contaminant concentrations should be able to re-create historical and present day contaminant concentrations.

4. Page 4. "Compounds of Concern"

   Three compounds are proposed for transport simulation based on their transport characteristics and carcinogenic nature. Please identify and simulate the transport of the top three compounds that are important to human and environmental risk analyses.

5. Page 5. "Model Grid and Layers"

   Give examples of particular technologies that may require extremely fine grid cells.

6. Page 6. "Hydraulic Parameters"

   Will the funnel and gate and pumping alternatives operate long enough to establish steady-state conditions? Indicate likelihood that these alternatives will operate as transitory measures.

7. Page 7. "Hydraulic Parameters"

   Use past pump test data to estimate vertical hydraulic conductivity. Use measured estimate in addition to assumed ratios.

8. Page 7. "Chemical Parameters"

   As proposed on page 3, the model will be calibrated to long-term transport conditions. Use calibration results to zero in on a realistic range of values.

9. Figure 2-1 and 2-2. Show piezometric surfaces for minimum and maximum water levels. Show dates of water level elevation measurements. Or, refer reader to document where this information is shown.

10. Figures 3-1 and 3-2. Show dates of water level measurements. Provide statements on any changes to flow direction patterns based on seasonal and biannual lake level changes. Or, refer reader to where this is discussed.

To: Brian Sato

From: Ching-Pi Wang

Date: January 17, 1997

Subj: Baxter/Quendal/JAG Subsurface Modeling Expectations

1. Utilize model sophistication comnmensurate for level of confidence in input data.

2. Provide clear illustrations of conceptual flow and transport models.

3. Provide range of model estimates for uncertainties in model input parameters.

4. Show boundary conditions and distribution of simulated hydrogeologic and transport properties.

5. Show simulation grid(s) superimposed on conceptual models.

6. Don't feel reluntant to state uncertainties and unknowns.

7. Provide clear illustrations of simulation results.

8. Provide time and concentration predictions of contaminant transport in ground water.

9. Provide time and concentration predictions of contaminant transport to Lake Washington via ground water.

10. Provide estimates of total contaminant flow into Lake Washington for 1, 2, 3, 4, 5, 10, 15, 20, 25, and 30 year periods.

11. Provide time and concentration predictions of contaminant transport in ground water for each increment of subsurface remediation effort. For example, if an impermeable cover is installed then estimate the amount of contaminant transport reduced by this measure.

12. Provide time and concentration predictions of contaminant transport to Lake Washington for each increment of subsurface remediation effort. For example, if a hanging slurry wall is installed near the lake shore, then estimate the amount of contaminant transport reduced by this measure.

13. Provide estimates of total contaminant transport and flow into Lake Washington for 1, 2, 3, 4, 5, 10, 15, 20, 25, and 30 year periods for each combination of subsurface remediation effort.

14. Identify locations of downgradient lakeside monitoring wells in the model simulation. Estimate contaminant concentrations at those locations for 1, 2, 3, 4, 5, 10, 15, 20, 15, and 30 year periods. Install monitoring wells in the simulated locations. Sample the monitoring wells for the same modeling periods. Compare simulated results to actual water quality results for the simulated time periods. Adjust simulations and predictions, if necessary, for each incremental period if initial simulated results do not match actual future concentrations.

15. Provide hypothesis(es) of preferential flow path distribution. Simulate the hypothesis(es). Provide estimates of contaminant transport and loading into Lake Washington.

16. Provide hypothesis(es) of DNAPL distribution. Simulate the hypothesis(es). Provide estimates of contaminant transport and loading into Lake Washington.

17. Provide hypothesis(es) of DNAPL migration. Simulate the hypothesis(es). Provide estimates of contaminant transport and loading into Lake Washington.

18. Identify locations of monitoring wells near the edge of known DNAPL occurrences. Install monitoring wells in the simulated locations. Estimate contaminant concentrations at those locations. Compare simulated results to actual future concentrations. Adjust model simulations and predictions if necessary.

19. If DNAPL areas are excavated, then compare field observations of DNAPL distribution to model hypothesis(es) of DNAPL distribution. Adjust model predictions if necessary.

20. Please do not hesitate to contact me for consultation or clarification. My contact numbers are: voice: (206) 649-7134; fax: (206) 649-7098; email: cwan461@ecy.wa.gov

RETEC

MEMORANDUM

TO:	Brian Sato, P.E. Ching-Pi Wang, P.E.	**DATE:**	May 2, 1997
FROM:	Stephen Codrington - RETEC Mike Riley - Papadopulos	**RE:**	Port Quendall Project - Follow up to 4/22/97 Ecology meeting

This memorandum provides follow up to our April 22 meeting regarding the groundwater modeling memorandum (April 4, 1997).

1 Purpose

The groundwater model memorandum discussed the objectives of the groundwater modeling effort. However, these objectives should be viewed within the context of the project as a whole. The groundwater modeling serves two purposes within the project scope: evaluation of remedial alternatives and contaminant transport analysis. The level of detail in the model and the modeling effort is limited to the level of analysis sufficient to achieve these purposes.

Analysis of Alternatives: At the time that the groundwater memorandum was prepared, the final list of remedial alternatives was not finalized. Since that time, a list of six remedial alternatives have been scoped (Memorandum from John Ryan to Brian Sato, dated April 21, 1997). Additional alternatives will be developed as we get more input from the stakeholders. The groundwater model will be used to evaluate the relative benefits of each alternative with respect to groundwater containment at the site (Table 1). Each alternative consists of one or more remedial technologies. The groundwater model will be applied to each alternative and will simulate the effect of all the technologies that make up an alternative. For instance, if an alternative includes both a containment wall and an upland cap, the model will be modified to simulate the combined effect of a cap and wall on groundwater containment. Alternatives will be compared using particle tracking analysis to predict exposure points, velocities, and travel times from selected areas of the site to Lake Washington.

Contaminant Transport Analysis: Action levels for groundwater cleanup alternatives can be determined at selected well locations and depths based on the groundwater model and a transport analysis. Predictions of flow characteristics are a normal output from the modeling effort and will form the basis of the transport analysis. There are several approaches that can be applied in a transport analysis including numerical modeling, analytical modeling, or travel-time-based analysis. The approaches differ with respect to the level of effort and the detail in output. Our approach is to select a transport analysis that is sufficient for determining containment of groundwater and action levels that indicate when additional remedial technologies have to be implemented in order to protect water quality in Lake Washington. The most cost-effective method of achieving this end is the travel-time-based analysis.

A more detailed discussion of the advantages and disadvantages of the different approaches is provided below in Section 5.

2 Calibration

Issues related to calibration of the model were limited to selection of an appropriate calibration data set and comparison to hydraulic properties used in previous modeling efforts in the project area (Hart Crowser, Draft Remedial Investigation Report for Quendall Terminals, October 1, 1996).

Water levels: At the request of Ecology, a two-step calibration will be done using water level data collected during August 1995 and January 1996 (Figures 1 and 2). The wells illustrated in figures 1 and 2 are all shallow wells with the exception of BH-17B, BH-18B, BH-20B, BH-21B and BH-5. The data sets were selected to represent high and low water levels at the site corresponding to the summer dry season and the winter rainy season in the Seattle area. Model calibration will consist of changing recharge and boundary conditions to achieve a subjective "best fit" between predicted and measured water levels without changing hydraulic properties of the aquifer between calibration steps. Application of the model for the analysis of alternatives will be done using average recharge and boundary conditions from the two steps in the model calibration, since the average annual conditions are representative of long-term groundwater flow and contaminant transport at the project area.

Hydraulic conductivity: Ecology requested that a comparison be made between the current modeling and previous modeling at the site (Hart Crowser, Draft Remedial Investigation Report for Quendall Terminals, October 1, 1996). Since previous modeling consisted only of a simplified, two-dimensional model, a direct comparison to the current three-dimensional modeling effort is not appropriate. However, a comparison of the hydraulic properties used in each model can be made. At this time, it is expected that the horizontal hydraulic conductivity of the silty-peat layer used in the current model will be greater than that used in the previous modeling. The higher value is consistent with the geometric mean of hydraulic conductivity data computed by

Hart-Crowser. However, a lower value was used in their model. The previous modeling also used two values for the horizontal hydraulic conductivity for the sand layer. It is expected that the current model will use a single value for the sand layer that is expected to be similar to the geometric mean of the two values used previously.

At the request of Ecology, the use of ratios between horizontal and vertical hydraulic conductivities was revisited. There are no data supporting the vertical hydraulic conductivity value used in the previous modeling effort. The selected values indicate that a simple 10:1 ratio was used between horizontal and vertical hydraulic conductivity. Previous work by Woodward-Clyde (Remedial Investigation Report, Baxter Property, December 1990) shows estimated vertical hydraulic conductivities for fine-grained layers in the range of 0.05 and 0.005 ft/day. The simple ratio of 100:1 proposed in our modeling effort results in a vertical hydraulic conductivity in the silty-peat layer that falls within this range.

3 Compounds of Concern

Ecology requested more detail on the process for selecting compounds of concern. The compounds were divided into groups based on properties and chemical structure. This results in a set of light, volatile hydrocarbons (BTEX group); light semi-volatile polycyclic aromatic hydrocarbons of two or three rings (LPAHs), and heavy semi-volatile polycyclic aromatic hydrocarbons of four or more rings (HPAHs). The objective was to select the compound that was most easily transported, had the highest concentration, and the greatest threat to human health and the environment. Transport potential was determined by comparing literature values for retardation rates with low retardation rates indicating more readily transported compounds. The highest concentration observed for a compound in ground water at the site was used in the comparison. The comparison of the threat to human health and the environment was made by comparing reference dose for non-carcinogens and cancer slope factors for carcinogens. Between carcinogens and non-carcinogens in a group, the preference was to consider carcinogens as a greater threat.

Among the BTEX compounds, benzene is found at the highest concentration, is the most readily transported, and the only carcinogen in the group. Consequently, benzene was selected as a compound of concern.

Among the LPAHs, naphthalene is found at the highest concentration and is the most readily transported. Naphthalene does not have the highest reference dose, but the concentration is so much greater than the other LPAHs, that it was selected as the primary compound of concern for this group. Since none of the LPAHs are carcinogens, this was not a factor in the selection.

The HPAHs show a wide range of variability in retardation rate, health factors, and concentration. Of the carcinogens, benzo(a)pyrene is considered the most significant. However, chrysene is found at higher concentrations and has a considerably lower retardation factor. Consequently, it is more readily transported although it has a slightly lower carcinogenic potential. Based on this, chrysene was selected over benzo(a)pyrene although either could have been selected. At this time, it is proposed to include both in the transport analysis.

The final compound of interest in the project area is pentachlorophenol. It is found only in one small area within the project boundaries and at concentrations below the MTCA Method B formula values for non-carcinogens in surface water. Consequently, it was not proposed for the transport analysis. However, this may change depending on the approach selected for the transport analysis.

The data used for the selection of compounds of concern was presented in Table 5-1 of the groundwater memorandum and provided here as Table 2.

4 Analysis of Alternatives

The groundwater flow model will be used to analyze the various alternatives under consideration for the site (see Table 1). All alternatives involve some level of source area removal, although the extent of this action varies among the alternatives. Four alternatives include some form of containment wall and five alternatives include capping of some areas with soils above MTCA Method B concentrations. Comparisons among the alternatives will be made using particle path analysis to show how an alternative affects flow paths and travel times between areas with elevated concentrations in ground water and Lake Washington. In addition, particle tracking will be used to illustrate the capture zone and effectiveness of backup pump-and-treat systems. Particle tracking analysis is a well accepted and effective method for computing travel times and estimating capture zones.

The following is a brief discussion of each alternative and how the alternatives will be simulated in the model.

Alternative A: This alternative consists of only source area removal including all soils above MTCA Method B concentration. From a groundwater modeling standpoint, this is the no action alternative as extant ground water at the site will not be contained or removed and no physical barriers or caps will be used to impede or reduce groundwater flow. All other groundwater alternatives will be compared to this alternative to illustrate the relative effectiveness of the various controls included in the other alternatives.

Alternative B: This alternative includes more limited soil removal than Alternative A. Soils above a concentration that is protective of ground water will be removed and those areas with soil above MTCA Method B will be capped. There is no practical difference between alternative A and B in the context of groundwater flow.

Alternative C: Alternative C consists of soil removal in areas containing DNAPL and capping of soils that exceed MTCA Method B concentrations. In addition, a slurry wall will be installed along the shoreline to prevent DNAPL seeps to the lake. The slurry wall will be analyzed by computing the harmonic mean hydraulic conductivity in the model along the proposed alignment of the slurry wall. The harmonic mean will be computed from the thickness and design hydraulic conductivity for the slurry wall and the calibrated hydraulic conductivity in the area of the slurry wall. Different wall depths will be simulated to determine the benefit of a deeper wall along the shoreline. Particle tracking and travel-time analysis will be used to illustrate changes in groundwater flow to Lake Washington.

Alternative D: This alternative only differs from Alternative C by including a contingent groundwater pump and treat system. The contingent groundwater pumping system would be used in the event groundwater exceeds action levels at a conditional point of compliance. The model will be used to design pump rates and capture zones for areas that are not protective of groundwater quality. Particle tracking will be used to illustrate the capture zone at the preferred pumping rate. Groundwater treatment by biosparging can be included in this model to show pathways and travel times through the biosparging zones. Locations for these zones will be taken from proposed wall designs. The actual effect of these zones will only be addressed in the transport modeling by changing the degradation rate in and beyond the biosparging zone.

Alternative E: This alternative is essentially the same as Alternative C except that the slurry wall has a slightly different alignment by extending slightly offshore. This change in alignment is not expected to change the model results. A test case for one wall depth will be run and compared to Alternative C results. If the travel times are essentially the same as those from Alternative C, then no other additional groundwater modeling will be required and results from Alternative C for different wall depths will be used.

Alternative F: This alternative is essentially the same as Alternative E and consequently no additional groundwater modeling is required for this alternative.

5 Transport Analysis

As discussed in Section 1 above, there are several approaches to the transport analysis that could be applied for this project. The approaches vary primarily by the level of effort and the detail in the output. Basically, the approaches fall into three general categories: numerical models, analytical models, and travel-time analysis. Each of these are discussed below.

Numerical models: These provide the most detail on distribution, transport, and chemical fate of compounds included in the model analysis. Numerical models also require the greatest level of effort. Consequently, there is a trade-off between what the model provides and the level of effort required. Numerical models are appropriate where there is a need for prediction of long-term trends and variation in plumes over large areas. They are particularly necessary where heterogeneities are too great to be adequately incorporated in more simplified analytical models.

Output from numerical models consists of predication of concentration over space and time. This information shows:

- Estimates of plume orientation over time and potential for downgradient users to be affected

- Estimates of time for cleanup for different remedial alternatives where cleanup as opposed to containment is the objective of the remediation

- An estimate of the concentration at extraction wells for design of treatment systems

While other methods can be used to make some of these estimates, numerical modeling provides the most rigorous approach as it incorporates the greatest amount of site detail in the analysis.

Analytical models: Analytical models are appropriate for analysis of homogeneous sites with simple groundwater flow patterns. Since analytical models are limited to uniform flow fields and homogeneous conditions, they are not appropriate for the present case where both vertical and horizontal flow are potentially important contaminant transport pathways and hydraulic properties vary vertically.

Travel-time analysis: This is basically a spread-sheet analysis using particle path analysis from the groundwater flow model to assess the time of travel from one point to another. Retardation rates are used to predict the difference in travel time for different compounds. Degradation rates are used to predict the degradation of the compound over time between the points of interest. Since the analysis is done on a spread-sheet and not in a detailed numerical model, there is little additional effort required to include more compounds in the analysis. Consequently, the compounds of concern could be expanded to include all the compounds in Table 2 with little additional effort.

The travel-time approach is a simplified transport analysis using the output from the groundwater flow model. Consequently, it makes maximum use of site data, while provided a cost-effective means of estimating the change of concentration over localized areas. This approach is appropriate for determination of action levels at selected points such as existing monitoring wells based on the travel time and degradation between the well and a point of exposure.

The procedure for applying this method requires several steps that begin with application of the groundwater flow model:

1) Run groundwater flow model to generate flow field for a remedial alternative.
2) Run particle tracking from selected points of interest to determine points of exposure and hydraulic travel time.
3) Prepare data for retardation factors and degradation rates for compounds of concern.
4) Import predicted travel time results into the spreadsheet.
5) Use the spreadsheet to predict compound-specific travel times from the retardation factor.
6) Use the compound-specific travel time to predict the concentration at the point of exposure for the degradation rate of that compound.

There are several advantages of this approach for the prediction of action levels:

- Site-specific flow dynamics from the ground-flow model can be used
- Compound-specific retardation and degradation rates can be incorporated. These may be generated from laboratory testing, data analysis, or literature values, as appropriate

- A relatively large number of compounds can be investigated rather than just a few selected compounds of concern

- Retardation factors and degradation rates are easily modified to test sensitivity of estimates

Based on these advantages, the cost-effectiveness of the approach, and the focus of the analysis on determining action levels, the travel-time approach is both adequate and appropriate as a transport analysis for the Port Quendall Development project.

Table 1 Conceptual Remedial Alternatives

	Soil	Sediments	Groundwater	Containment Wall	Cap	Institutional Controls	Mitigation
A	excavation/treatment of soil greater than Method B	removal/treatment of more than 50% wood waste, PAH>100ppm	natural attenuation	none	none	groundwater monitoring	wetland replacement
B	excavation/treatment of soil greater than Groundwater Protection Standard	same as A	same as A	none	soils greater than Method B	monitoring and legal regulatory devices	same as A
C	excavation/treatment of DNAPL soil	same as A	biosparging	upland hanging wall	same as B	same as B	same as A
D	excavation/treatment of nearshore DNAPL	same as A	Biosparging and groundwater treatment	same as C	same as B	same as B	same as A
E	hazardous waste removal	same as A	D + DNAPL Recovery	nearshore hanging wall	same as B	same as B	A + nearshore
F	no removal/waste stabilization	removal of more than 50% wood waste	same as E	same as E	B + sediments	B + sediment monitoring	same as E

Table 2 Compounds of Concern in ground water samples

								Reference Dose Mg/Kg/Day				Cancer Slope Factor Mg/Kg/Day				
	Detections	Analyses	Detection %	Max. Conc (ug/L)	Solubility Limit mg/L	Retardation Factor	# of Rings	Oral	Ref.	Inhalation	Ref.	Oral	Ref.	Inhalation	Ref.	Carcinogen
Pentachlorophenol	3	130	2%	630	5mg/L@0'C / 14mg/L@20'C	7	1	3.00E-02	R	1.20E-01	R	-	R	-	R	No
Benzene	37	113	33%	14000	1780 mg/L@20'C	1	1	-	R	1.70E-03	R	2.90E-02	A	2.90E-02	A	Yes
Toluene	54	108	50%	3400	470mg/L@16'C / 515 mg/L@20'C	2	1	2.00E-01	A,R	1.14E-01	-	-	R	-	R	No
Ethylbenzene	38	113	34%	3800	140 mg/L@15'C / 152mg/L@20'C	6	1	1.00E-01	A	2.86E-01	A	-	R	-	R	No
o-Xylene	10	26	38%	510	175 mg/L@20'C	NA	1	2.00E+00	R	2.00E-01	R	-	R	-	R	No
m-,p-Xylene	12	26	46%	1000	198mg/L@25'C(p-xylene)	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	No
xylene (total)	44	106	42%	7800	NA			2.00E+00	A,R	2.00E+00	A	-	R	-	R	No
Naphthalene	72	121	60%	43000	31-34mg/L in distilled water@25'C	7	2	4.00E-03	A	4.00E-03	A	-	R	-	R	No
Acenaphthene	59	121	49%	1900	NA	23	3	6.00E-02	R	6.00E-02	R	-	R	-	R	-
Acenaphthylene	25	121	21%	2300	3.93 mg/L in distilled@25'C	13	3	4.00E-03	-	4.00E-03	-	-	-	-	-	No
Anthracene	35	121	29%	1200	.075 mg/L@15'C	69	3	3.00E-01	A	3.00E-01	R	-	R	-	R	No
Fluorene	56	121	46%	2200	1.9 mg/L@25'C	36	3	4.00E-02	A	4.00E-02	A	-	R	-	R	No
Phenanthrene	50	121	41%	6200	1.6mg/L@15'C	69	3	4.00E-03	-	4.00E-03	-	-	-	-	-	No
Benzo(a)anthracene	31	121	26%	1100	0.044mg/L@24'C (practical grade)	6,704	4	-	R	-	R	7.30E-01	R	6.10E-01	R	Yes
Chrysene	29	121	24%	1700	0.0015@15'C / 0.006mg/L@25'C	972	4	-	A	-	A	1.15	A	1.15	A	Yes
Fluoranthene	46	121	38%	2800	0.120mg/L@24'C (99%purity)	186	4	4.00E-02	A	4.00E-02	A	-	R	-	R	No
Pyrene	41	121	34%	2400	0.032mg/L (practical grade)	186	4	3.00E-02	R	3.00E-02	R	-	R	-	R	No
Benzo(a)pyrene	33	121	27%	1700	NA	26,715	5	-	R	-	R	7.3	R	6.1	R	Yes
Benzo(b)fluoranthene	14	47	30%	50	NA	2,672	5	-	R	-	R	7.30E-01	R	6.10E-01	R	Yes
Benzo(k)fluoranthene	12	59	20%	46	NA	2,672	5	-	R	-	R	7.30E-02	R	6.10E-02	R	Yes
Dibenz(a,h)anthracene	14	121	12%	420	NA	16,030	5	-	R	-	R	7.3	R	6.1	R	Yes
Benzo(g,h,i)perylene	15	121	12%	1000	NA	7,772	6	4.00E-03	-	4.00E-03	-	-	-	-	-	No
Indeno(1,2,3-cd)pyrene	14	76	18%	830	NA	7,772	6	-	-	-	-	7.30E-01	-	6.10E-01	-	Yes
Dibenzofuran	37	99	37%	1500	NA	55		4.00E-03	R	-	R	-	R	-	R	No

NOTES:

The detections and analysis statistics are compiled from the Retec database for Quendall Properties

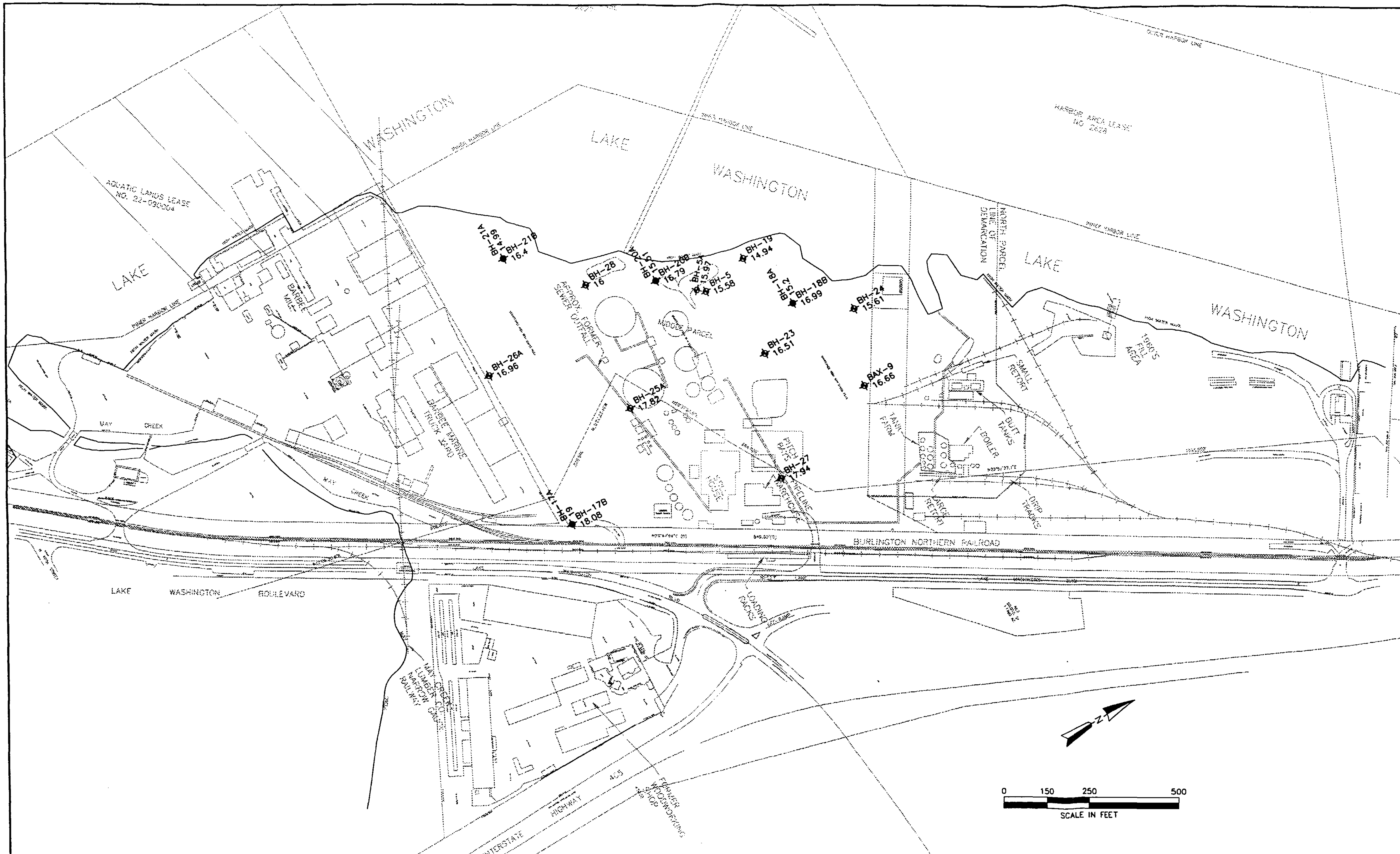
Retardation factors are tabulated in Table XX, shown in appendix XX.

References

R - US EPA Region III Risk Based Concentration Table, EPA Region 3, March 7, 1995

A - Emergency Standard Guide for Risk Based Corrective Action Applied at Petroleum Release Sites, ASTM, ES 38-94

Solubility Limit taken from "Handbook of Environmental Data on Organic Chemicals, 2nd Edition, Karel Verschueren, Van Nostrand Reinhold, New York, 1983



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		1							
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AUGUST 1995 WATER LEVELS
ELEVATIONS IN FEET ABOVE MSL

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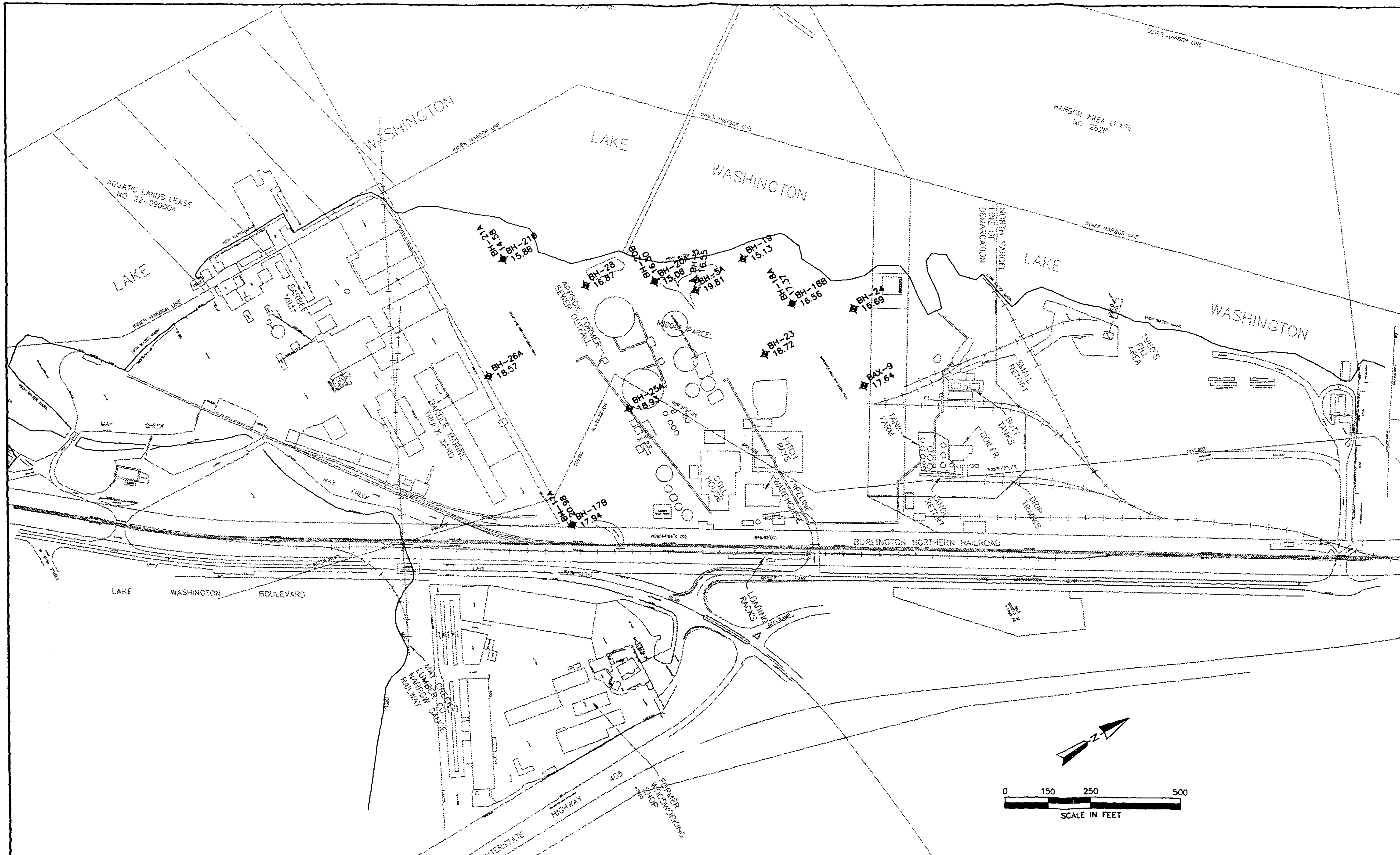

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REFERENCE DWG	DESCRIPTION	NO	DRWN	DATE	REVISION	CHKD	DATE	APPVD	DATE

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JANUAREY 1996 WATER LEVELS
ELEVATIONS IN FEET ABOVE MSL

RETEC
REMEDIATION TECHNOLOGIES INC

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Appendix A10

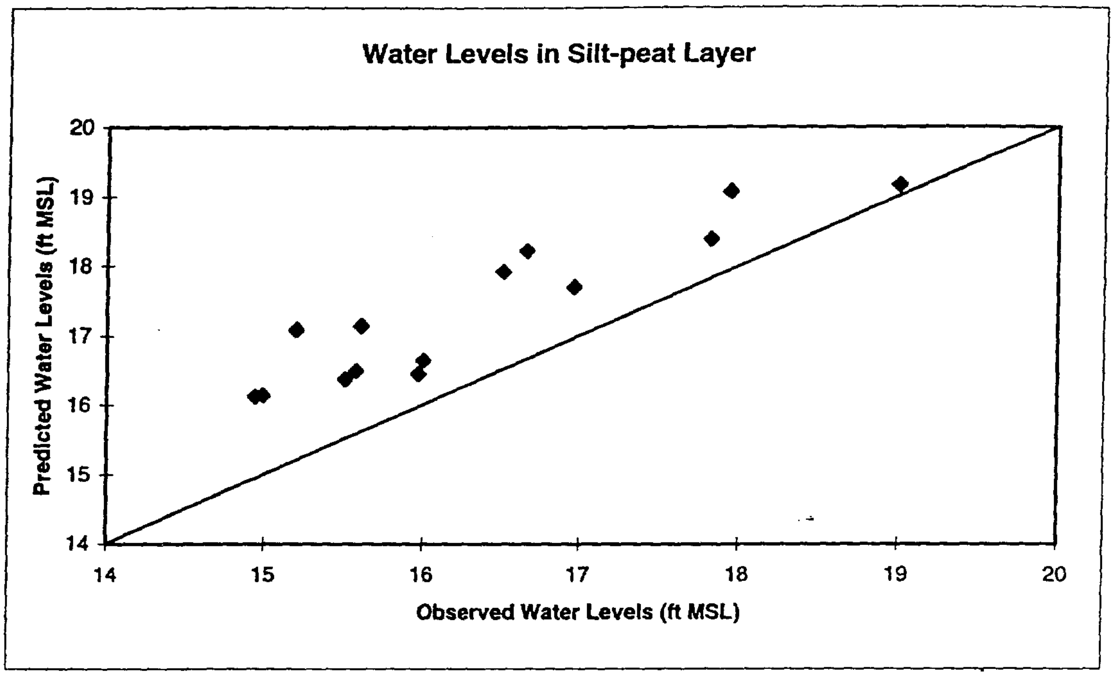
Model Calibration Documentation

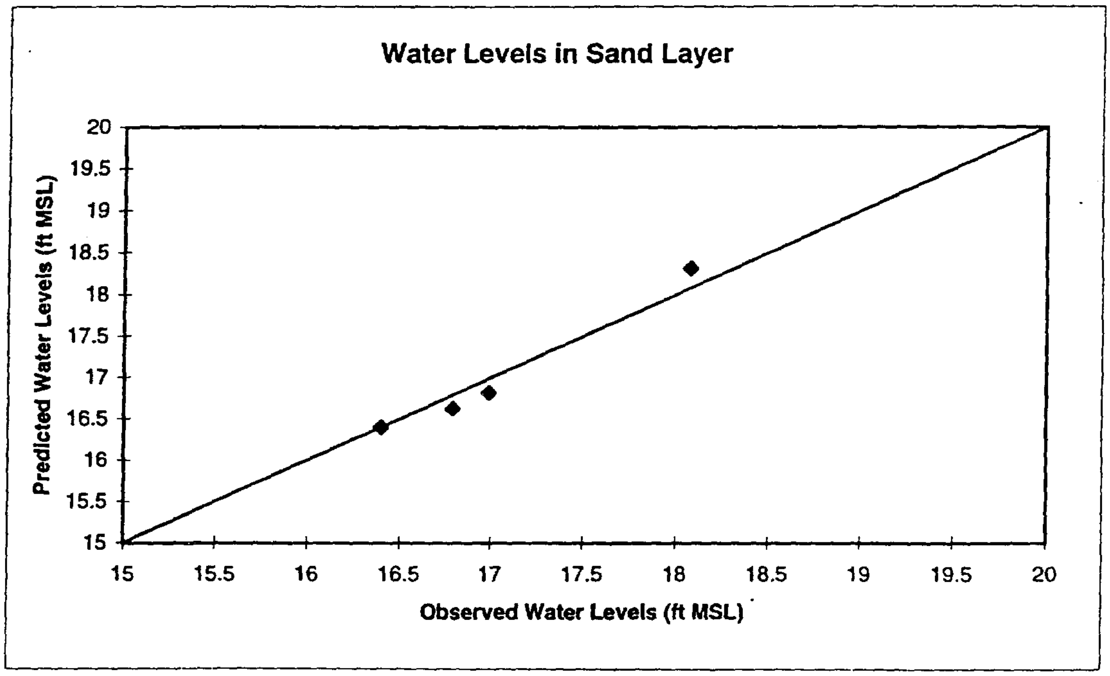
Calibration Water Level Data Sets

Well ID	Coordinates East-West	Coordinates North-South	Model Layer	Water Level (ft MSL) Average	Water Level (ft MSL) Aug-95	Water Level (ft MSL) Jan-96
B-1	1662691	196518	Silt-peat	22.30		
B-3	1662949	196509	Silt-peat	22.40		
BAX-1	1662958	197926	Silt-peat	16.88		
BAX-10	1663122	198530	Silt-peat	17.55		
BAX-11	1662854	197932	Silt-peat	16.88		
BAX-1A	1662967	197944	Silt-peat	16.91		
BAX-5	1662502	198159	Silt-peat	14.77		
BAX-6	1663129	198833	Silt-peat	14.13		
BAX-7A	1663462	197963	Silt-peat	24.60		
BAX-8A	1662527	198031	Silt-peat	15.70		
BAX-9	1662585	197762	Silt-peat	17.16	16.66	17.64
BH-12	1661825	197122	Silt-peat	18.33		
BH-17A	1662512	196838	Silt-peat	20.13	19.60	20.98
BH-18A	1662281	197707	Silt-peat	16.24	15.20	17.37
BH-19	1662102	197650	Silt-peat	15.07	14.94	15.13
BH-20A	1662029	197396	Silt-peat	15.40	15.51	15.08
BH-21A	1661758	197052	Silt-peat	14.62	14.99	14.58
BH-22	1662937	197562	Silt-peat	19.96		
BH-23	1662367	197566	Silt-peat	18.23	16.51	18.72
BH-24	1662381	197850	Silt-peat	16.34	15.61	16.69
BH-25A	1662307	197149	Silt-peat	18.61	17.82	18.93
BH-26A	1662026	196848	Silt-peat	17.96	16.96	18.57
BH-27	1662698	197423	Silt-peat	18.88	17.94	
BH-28	1661940	197219	Silt-peat	16.82	16.00	16.87
BH-5	1662129	197508	Silt-peat	17.17	15.58	16.55
BH-5A	1662110	197486	Silt-peat	17.17	15.97	
GB-1	1663000	196205	Silt-peat	29.20		
BH-17B	1662511	196838	Sand	18.14	18.08	17.94
BH-18B	1662281	197707	Sand	16.89	16.99	16.56
BH-20B	1662028	197395	Sand	16.66	16.79	16.30
BH-21B	1661757	197052	Sand	16.26	16.40	15.88
BH-25B	1662306	197149	Sand	17.45		
BH-26B	1662025	196847	Sand	16.94		

Table 2-4 Calibration Statistics

Calibration Data Set	Layer	Number of Observations	Mean Residual (ft)	Root Mean Square Residual (ft)	Correlation Coefficient
August-95	Silt-peat	14	1.01	1.11	
	Sand	4	-0.28	0.17	
	All	18	0.78	0.98	0.846
Janurary-96	Silt-peat	12	-0.23	0.76	
	Sand	4	-0.11	0.27	
	All	16	-0.20	0.67	0.932
Average	Silt-peat	27	-0.14	2.23	
	Sand	6	-0.03	0.17	
	All	33	-0.11	2.02	0.829





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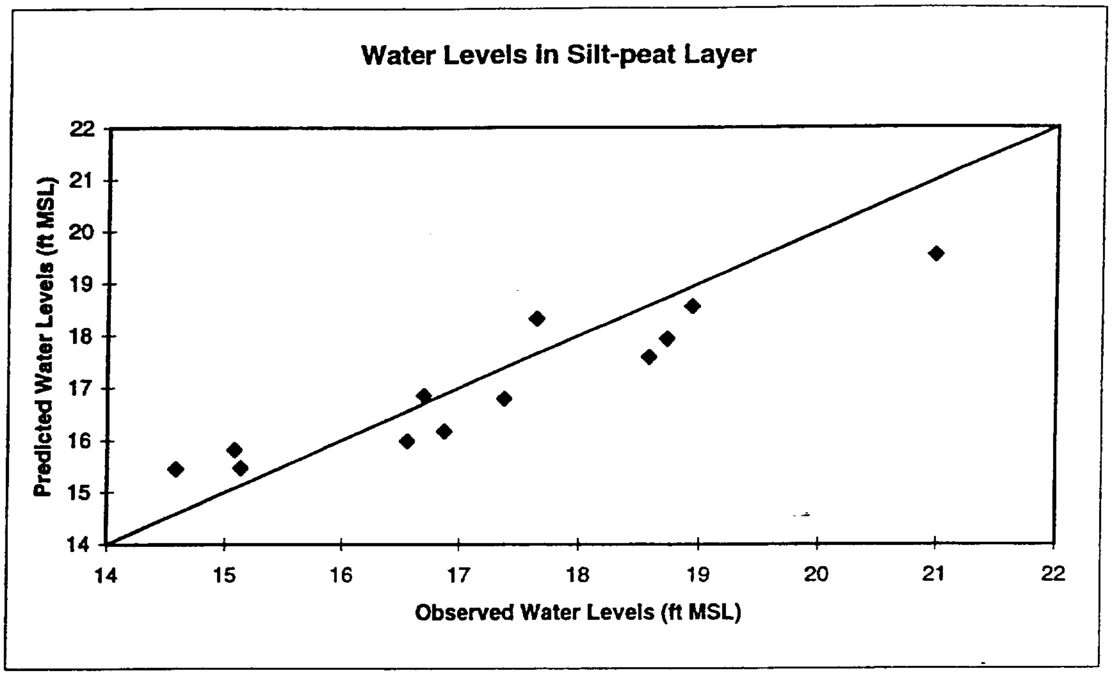
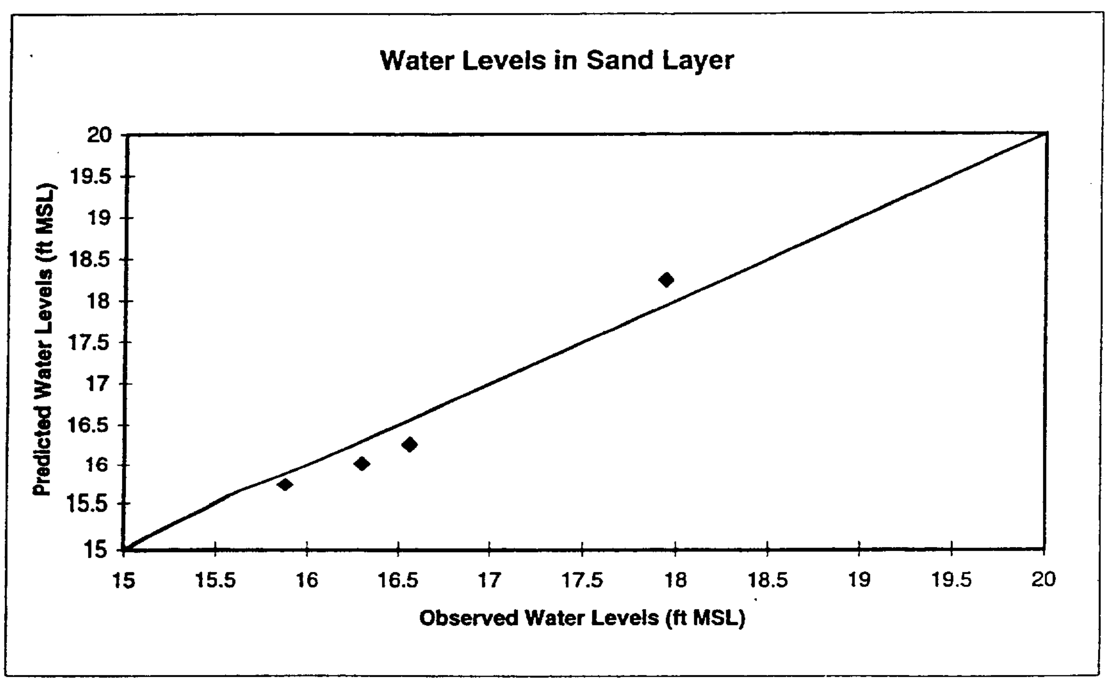
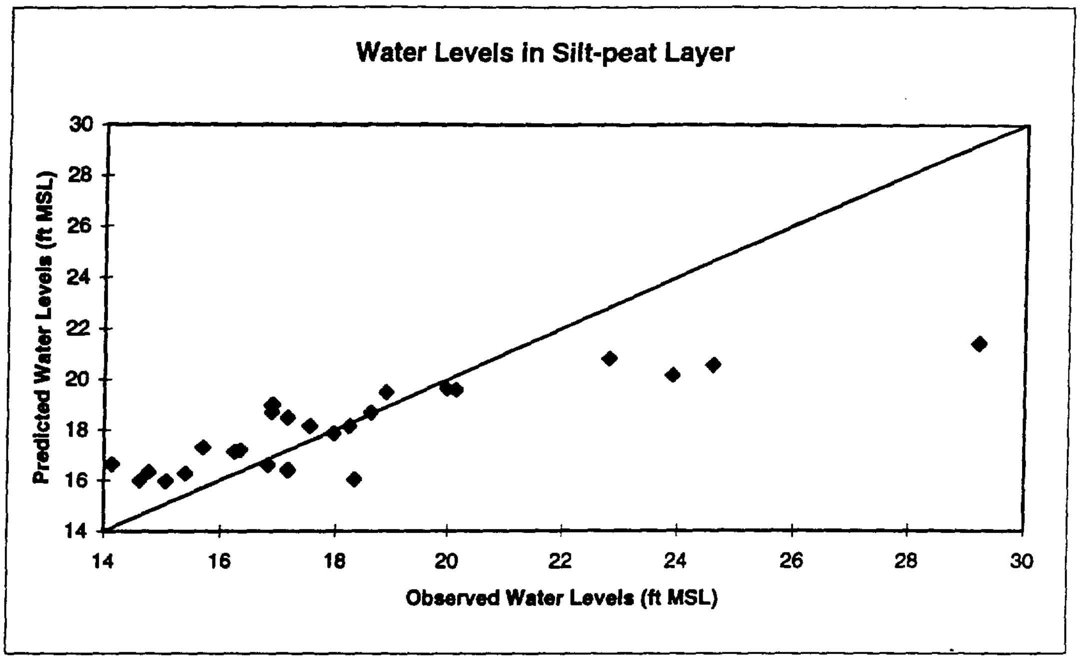
Comparison between model results and water level data for August 1995

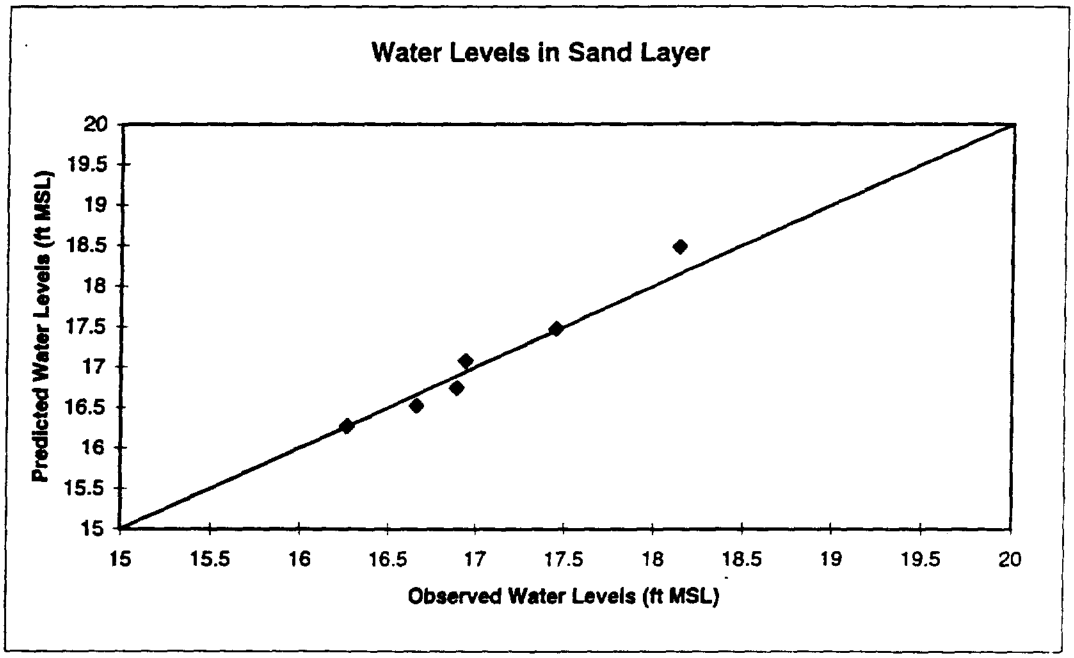
2-11





S.S. PAPADOPULOS & ASSOCIATES, INC. ENVIRONMENTAL & WATER-RESOURCE CONSULTANTS	**Comparison between model results and water level data for January 1996**	**2-12**





Comparison between model results and average water level data